3

Affected Environment

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3. AFFECTED ENVIRONMENT

To analyze potential environmental impacts that could result from the implementation of the Proposed Action, the U.S. Department of Energy (DOE) has compiled extensive information about the environments that could be affected. The Department used this information to establish the *baseline* against which it measured potential impacts (see Chapter 4). Chapter 3 describes (1) environmental conditions that will exist at and in the region of the proposed repository site at Yucca Mountain after the conclusion of site characterization activities (Section 3.1); (2) environmental conditions along the proposed transportation corridors in Nevada that DOE could use to ship spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site (Section 3.2); and (3) environmental conditions at the 72 commercial and 5 DOE sites in the United States that manage spent nuclear fuel and high-level radioactive waste (Section 3.3).

DOE obtained baseline environmental information from many sources. These sources included reports and studies sponsored by DOE, other Federal agencies (for example, the U.S. Geological Survey), and the State of Nevada and affected units of local government. Affected units of local government include Nye County, which is the county in which the repository site is located, by DOE decision as allowed under the Nuclear Waste Policy Act, as amended (this EIS refers to the amended Act as the NWPA), counties contiguous to Nye County (that is, Clark, Lincoln, White Pine, Eureka, Lander, Churchill, Mineral, and Esmeralda Counties in Nevada and Inyo County in California). In addition, DOE has sought input from Elko County, Nevada, which could be affected by transportation activities associated with the Proposed Action.

DOE received reports from the State of Nevada and affected units of local government during the EIS scoping process, informally from local government personnel, and formally during ongoing interactions between DOE and State and local governments. The subjects of these reports include socioeconomics, cultural resources, hydrology, transportation planning and emergency response, and resource supply. DOE evaluated these reports and, where appropriate, they are discussed in individual resource area sections of the EIS.

3.1 Affected Environment at the Yucca Mountain Repository Site at the Conclusion of Site Characterization Activities

To define the existing environment at and in the region of the proposed repository, DOE has compiled environmental baseline information for 13 subject areas. This environment includes the manmade structures and physical disturbances from DOE-sponsored site selection studies (1977 to 1988) and site characterization studies (1989 to 2001) to determine the suitability of the site for a repository. This chapter and supporting documents, called *environmental baseline files,* contain baseline information for:

- *Land use and ownership:* Land-use practices and land ownership information in the Yucca Mountain region (Section 3.1.1)

- *Air quality and climate:* The quality of the air in the Yucca Mountain region and the area's climatic conditions (temperature, precipitation, etc.) (Section 3.1.2)

- *Geology:* The geologic characteristics of the Yucca Mountain region both at and below the ground surface, the frequency and severity of seismic activity, volcanism, and mineral and energy resources (Section 3.1.3)

- *Hydrology:* Surface-water and groundwater features in the Yucca Mountain region and the quality of the water (Section 3.1.4)

- *Biological resources and soils:* Plants and animals that live in the Yucca Mountain region, the occurrence of special status species and *wetlands*, and the kinds and quality of soils in the region (Section 3.1.5)

- *Cultural resources:* Historic and archaeological resources in the Yucca Mountain region, the importance those resources hold, and for whom (Section 3.1.6)

- *Socioeconomic environment:* The labor market, population, housing, some public services, real *disposable income*, *gross regional product*, government spending, and DOE payment equal to taxes in the Yucca Mountain region (Section 3.1.7)

- *Occupational and public health and safety:* The levels of radiation that occur naturally in the Yucca Mountain air, soil, animals, and water; radiation dose estimates for Yucca Mountain workers from *background radiation*; radiation exposure, dispersion, and accumulation in air and water for the Nevada Test Site area from past nuclear testing and current operations; and public radiation dose estimates from background radiation (Section 3.1.8)

- *Noise and Vibration:* Noise and vibration sources and levels of noise and vibration that commonly occur in the Yucca Mountain region during the day and at night, and the applicability of Nevada standards for noise in the region (Section 3.1.9)

- *Aesthetics:* The visual resources of the Yucca Mountain region in terms of land formations, vegetation, and color, and the occurrence of unique natural views in the region (Section 3.1.10)

- *Utilities, energy, and materials:* The amount of water available for the Yucca Mountain region, water-use practices, water sources, the demand for water at different times of the year, the amounts of power supplied to the region, the means by which power is supplied, and the availability of natural gas and propane (Section 3.1.11)

- *Waste and hazardous materials:* Ongoing solid and hazardous waste and wastewater management practices at Yucca Mountain, the kinds of waste generated by current activities at the site, the means by which DOE disposes of its waste, and DOE recycling practices (Section 3.1.12)

- *Environmental justice:* The locations of *low-income* and *minority populations* in the Yucca Mountain region and the income levels among low-income populations (Section 3.1.13)

DOE evaluated the existing environments in regions of influence for each of the 13 subject areas. Table 3-1 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict impacts, if any, related to the proposed repository. Human health risks from exposure to airborne *contaminant* emissions were assessed for an area within approximately 80 kilometers (50 miles), and economic effects, such as job and income growth, were evaluated in a three-county socioeconomic region.

In the past, the vicinity around Yucca Mountain has been the subject of a number of studies in support of mineral and energy resource exploration, nuclear weapons testing, and other DOE activities at the Nevada Test Site. From 1977 to 1988, the Yucca Mountain Project performed studies to assist in the site selection process for a repository. These studies, which involved the development of roads, drill holes, trenches, and seismic stations, along with non-Yucca Mountain activities, disturbed about 2.5 square kilometers (620 acres) of land in the vicinity of Yucca Mountain (DIRS 104854-YMP 1998, p. 1). Yucca Mountain site characterization activities began in 1989 and continued through 2001. These activities include surface excavations, excavations of exploration shafts, subsurface excavations and borings, and testing to evaluate the suitability of Yucca Mountain as the site for a repository. As of 2001, these activities have

Table 3-1. Regions of influence for the proposed Yucca Mountain Repository.

Subject area	Region of influence
Land use and ownership	Land around site of proposed repository that DOE would disturb and over which DOE would need to obtain control; analyzed land withdrawal area is 600 square kilometers[a] (Section 3.1.1).
Air and climate	An approximate 80-kilometer[b] radius around Yucca Mountain, and at boundaries of controlled lands surrounding Yucca Mountain (Section 3.1.2).
Geology	The regional geologic setting and the specific geology of Yucca Mountain (Section 3.1.3).
Hydrology	*Surface water:* construction areas that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of the repository that would be affected by eroded soil or potential spills of contaminants.
	Groundwater: aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction, and aquifers downstream of the repository that repository use or long-term releases from the repository could affect (Section 3.1.4).
Biological resources and soils	Area that contains all potential surface disturbances resulting from the Proposed Action (described in Chapter 2) plus some additional area to evaluate local animal populations; roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (Section 3.1.5).
Cultural resources	Land areas that repository activities would disturb (described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur (Section 3.1.6).
Socioeconomic environment	Three Nevada counties (Clark, Lincoln, and Nye) in which repository activities could most influence local economies and populations (Section 3.1.7).
Occupational and public health and safety	An approximate 80-kilometer radius around Yucca Mountain and at the approximate boundary of analyzed land withdrawal area (Section 3.1.8).
Noise and vibration	Existing residences in the Yucca Mountain region and at the approximate edge of the analyzed land withdrawal area (Section 3.1.9).
Aesthetics	Approximate boundary of analyzed land withdrawal area (Section 3.1.10).
Utilities, energy, and materials	Public and private resources on which DOE would draw to support the Proposed Action (for example, private utilities, cement suppliers) (Section 3.1.11).
Waste and hazardous materials	On- and offsite areas, including landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of site-generated repository waste (Section 3.1.12).
Environmental justice	Varies with the different subject areas. The environmental justice regions of influence will correspond to those of the specific subject areas, as defined in this table (Section 3.1.13).

a. 600 square kilometers = about 150,000 acres or 230 square miles.
b. 80 kilometers = about 50 miles.

disturbed about an additional 1.5 square kilometers (370 acres) in the vicinity of Yucca Mountain (DIRS 104508-CRWMS M&O 1999, Table 6-2). Reclamation activities have started and will continue to occur as sites are released from further study.

The existing environment at Yucca Mountain includes the Exploratory Studies Facility, which includes the tunnel (drift), the North and South Portal pads and supporting structures, an excavated rock storage area, a topsoil storage area, borrow pits, boreholes, trenches, roads, and supporting facilities and disturbances for site characterization activities. Table 3-2 lists facilities, structures, equipment, and disturbances at Yucca Mountain and at the central support site in Area 25 of the Nevada Test Site. Area 25 was used in the early 1960s by the Atomic Energy Commission (a DOE predecessor agency) and the National Aeronautics and Space Administration as part of a program to develop nuclear reactors for use in the Nation's space program. The former Nuclear Rocket Development Station administrative areas complex in Area 25 has become the Yucca Mountain Site Characterization Central Support Site. As noted in the table, several of the Area 25 functions have been relocated to the North Portal site since the publication of the Draft EIS.

Table 3-2. Existing facilities, structures, and disturbances at Yucca Mountain.[a]

Yucca Mountain	Area 25 Central Support Site
Exploratory Studies Facility (North Portal pad and supporting structures)	Field Operations Center (moved)[b]
	Hydrologic research facility
Exploratory Studies Facility (South Portal pad)	Sample management facility and warehouse
Cross drift[c]	Radiological studies facility (moved)[b]
Concrete batch plant and precast yard	Meteorology/air quality studies facility (moved)[b]
Fill borrow pits (3) and screening plants	Project accumulation area for hazardous waste
Subdock equipment storage facility	Gas station
Equipment/supplies laydown yard	Maintenance facility
Hydrocarbon management facility	U.S. Geological Survey technical warehouse (moved)[b]
Boxcar equipment and supplies yard	
Water wells J-12 and J-13	Tunnel rescue facility
Excavated rock storage pile	Sewage lagoon operated by the Nevada Test Site
Topsoil storage pile	
Explosives storage magazines (2)	
Water booster pump and distribution system	
Boreholes (about 300)	
Trenches and test pits (about 200)	
Busted Butte geologic test drift	
Fran Ridge heated-block test facility	
Water infiltration test sites	
Meteorological monitoring towers	
Air quality monitoring sites	
Radiological monitoring sites	
Ecological study plots	
Reclamation study plots	
Septic system	
Roads	

a. Source: Modified from DIRS 148111-CRWMS M&O (1998, all) and DIRS 155933-Jacobs (2001, all).
b. These functions have been relocated to the North Portal site since the Draft EIS was published.
c. Drift is a mining term for a horizontal tunnel.

DOE has made revisions to this section since the Draft EIS to present newly acquired information that contributes to an improved (or updated) understanding of the potentially *affected environment* at Yucca Mountain and its region, and to include information and suggestions for improvement provided through public comments on the Draft EIS and the Supplement to the Draft EIS. The following items summarize key changes to the EIS that deal with the affected environment at the Yucca Mountain site:

- Corrections and updates were made to *land use* figures and text, including changes to the breakout of Nevada land by controlling authority to be consistent with recent land transactions. Clarification was provided on the statutory requirements associated with the proposed land withdrawal, on the rationale for the size of the withdrawal, and on the breakout of the agencies with administrative authority over the land.

- *Air quality and climate* text was modified to better describe the attainment status of areas outside the region of influence and to discuss Federal agency responsibilities under the *conformity* provisions of the Clean Air Act. A new section was added to describe paleoclimatology studies that have been performed as part of the Yucca Mountain Project.

- Minor text changes, including facts and figures, were made to both the *geology* and *hydrology* discussions in response to comments and to ensure consistency with updated information in the new primary source document, the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, all). Several geology and hydrology figures were improved with better graphics or additional information, and several figures were added.

- A new *geology* discussion was added on the formation and characteristics of fractures found in the rock at Yucca Mountain. An update was added to describe the status of ongoing efforts to monitor crustal strain rates in the area.

- Text was added or modified in *hydrology* discussions to better describe the direction of groundwater and the lack of water observed in the subsurface during tunneling at Yucca Mountain, and to provide information on the Devils Hole National Monument and on Nevada Test Site groundwater modeling efforts. Updates were added to describe the status of ongoing efforts to collect additional hydrologic information, including those resulting from the cooperative agreement between Nye County and DOE to investigate the groundwater flow system downgradient of Yucca Mountain. Updates were also added to discuss efforts to validate and verify chlorine-36 study results, and to study postulated evidence of past upwelling of the water table.

- The *biological resources* discussion of plant species in the area of Yucca Mountain was expanded to include identification of exotic species. Text was modified to describe more accurately the opposing viewpoint expressed by the State of Nevada with respect to the biological studies performed as part of the Yucca Mountain Project.

- *Socioeconomics* text and indicator numbers were revised to incorporate updated information from State of Nevada and local agency population estimates. Text was added to explain the basis for using these numbers rather than numbers anchored in 2000 Census data that became available since the publication of the Draft EIS. Socioeconomic indicator data (Gross Regional Product, government spending, and real disposable income) were added and discussions in several key areas were expanded to include estimates of socioeconomic indicators to 2035.

- The region of influence population *distribution* presented in the *occupational and public health and safety* discussion was changed to the new population estimates and is now described for both 2000 and 2035. The discussion of natural radiation sources was revised for clarity and accuracy. Tables and text were revised to better describe background/baseline radiation exposures and their effects at Yucca Mountain, in Nevada, and at other sites in the United States. A new section was added to discuss regional effects from past weapons testing at the Nevada Test Site.

- New text and a new table were added to the *noise* discussions to introduce the concept of vibration as an element of environmental assessment. The existing discussion of noise was augmented with a description of noise threshold levels that present hearing hazards as opposed to annoyance.

- Clarifying text was added to the *aesthetics* section's discussion of the Bureau of Land Management Visual Resource Management system, and particularly for the system's scenic quality component. Text was added describing nighttime darkness as an element of aesthetics for the Yucca Mountain region.

- Updated information was included in discussions of *utilities, energy, and site services*, as well as for *waste and hazardous materials*.

- *The environmental justice* discussion was expanded to better described the evaluation methodology and updated to incorporate 2000 Census data on minority communities. (The 1990 Census data still represents the most current available data for low-income communities.)

3.1.1 LAND USE AND OWNERSHIP

The *region of influence* for land use and ownership includes land at the site of the proposed repository that DOE would not disturb and the lands that surround the site of the proposed repository over which DOE would have to obtain permanent control to operate the repository. The Department has compiled land-use and ownership information for this region. Most of the land in the region is managed by agencies of the Federal Government. Sections 3.1.1.1 and 3.1.1.2 discuss land use and ownership for the region of influence and for a larger area around Yucca Mountain. Section 3.1.1.3 describes the *analyzed land withdrawal area* for the repository. Section 3.1.1.4 discusses Native American views about the ownership of the land around Yucca Mountain. The Environmental Baseline File for Land Use (DIRS 104993-CRWMS M&O 1999, all) is the basis of the information in this section unless otherwise noted.

3.1.1.1 Regional Land Use and Ownership

The Federal Government manages more than 85 percent of the land in Nevada (about 240,000 square kilometers or 93,000 square miles). Most of this land is under the control of the Bureau of Land Management (which is part of the U.S. Department of the Interior), the U.S. Department of Defense, and DOE. The remainder of the Federally managed land is primarily under the jurisdiction of the Forest Service, which is part of the U.S. Department of Agriculture, with smaller areas under the control of the National Park Service and the Bureau of Reclamation, both of which are parts of the Department of the Interior. About 42,000 square kilometers (16,000 square miles) are under State, local, or private ownership, and about 5,000 square kilometers (2,000 square miles) are Native American lands. Table 3-3 summarizes Nevada land holdings and the controlling authority. Figure 3-1 shows ownership and use of lands around the site of the proposed repository.

The Nevada Test Site, which is a DOE facility, covers about 3,700 square kilometers (1,400 square miles). The Atomic Energy Commission, a DOE predecessor agency, established the Nevada Test Site in the 1950s to test nuclear devices. More information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all). The U.S. Air Force operates the Nellis Air Force Range [its name recently changed to the Nevada Test and Training Range (DIRS 157220-BLM 2001, all)], which covers about 12,000 square kilometers (4,500 square miles) and is one of the largest and most active military training ranges in the United States. More information on current and future uses of the Nellis Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all). The Military Lands Withdrawal Act of 1999, approved by the passage of Public Law 106-65 on October 5, 1999, went into effect on

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Table 3-3. Nevada land areas and controlling authorities (square kilometers).[a,b]

Authority	Area	Percentage[c]
State, local, county, or private	42,000	15
Bureau of Land Management	194,000	68
Department of Defense	13,000	5
Department of Energy	3,700	1
Other Federal authorities	26,000	9
Native American tribes	5,000	2

a. Source: DIRS 104993-CRWMS M&O (1999, p. 1); DIRS 103472-USAF (1999, pp. 2-8 to 2-10); and DIRS 154121-DOI (2000, Volume I, p. 19)

b. To convert square kilometers to square miles, multiply by 0.3861.

c. Percentages calculated from area numbers prior to rounding and are shown to the nearest 1 percent.

November 6, 2001 and extended the affected land withdrawal until November 6, 2021. Actions taken under the Act at the Nellis Range also affected lands managed by the Bureau of Land Management and the Department of Energy (DIRS 103472-USAF 1999, pp. 2-8 to 2-10). Approximately 140 and 520 square kilometers (55 and 200 square miles) of land were transferred from the Department of Defense (that is, the Nellis Range) to the Bureau of Land Management (for public use) and DOE, respectively. Approximately 160 square kilometers (60 square miles) of land formerly withdrawn for use by DOE was transferred to the Department of Defense. The Nevada land areas and controlling authorities summarized in Table 3-3 incorporate these changes.

The region has special-use areas, which generally are excluded from development that would require terrain alterations unless such alterations would benefit wildlife or public recreation. The Fish and Wildlife Service of the U.S. Department of the Interior manages the Desert National Wildlife Range and the Ash Meadows National Wildlife Refuge, which are about 50 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively (Figure 3-1). These areas provide *habitat* for a number of resident and migratory animal species in relatively undisturbed natural ecosystems. The National Park Service manages Death Valley National Park, which is in California and Nevada approximately 35 kilometers (22 miles) southwest of Yucca Mountain. The small enclave of Devils Hole Protective Withdrawal in Nevada adjacent to the east-central boundary of Ash Meadows is also administered by the National Park Service (Figure 3-1). The Timber Mountain *Caldera* National Natural Landmark is located primarily on the Nellis Air Force Range and the Nevada Test Site. The Landmark is just north of the proposed repository withdrawal area. The Timber Mountain Caldera is also designated as an Area of Critical Environmental Concern (DIRS 157220-BLM 2001, p. 2-9).

CALDERA

A volcanic crater that has a diameter many times that of the vent. It is formed by collapse of the central part of a volcano or by explosions of extraordinary violence. The erupted materials are commonly spread over great distances beyond the caldera. Volcanic debris that erupted from the Timber Mountain and other calderas north of Yucca Mountain formed the southwestern Nevada volcanic field of which the volcanic rocks at Yucca Mountain are a part.

There is virtually no State-owned land immediately adjacent to the repository site. There are scattered tracts of private land in and near communities such as Beatty and Indian Springs in Nevada. There are also larger private tracts in the Las Vegas Valley, around Pahrump, and in the south-central portion of the large area that makes up Amargosa Valley. The closest year-round housing is at what was once referred to as Lathrop Wells, about 22 kilometers (14 miles) south of the site. This location is now part of the unincorporated Town of Amargosa Valley. There is farming—primarily grasses and legumes—for hay and dairy operations about 30 kilometers (19 miles) south of the proposed repository (Figure 3-1).

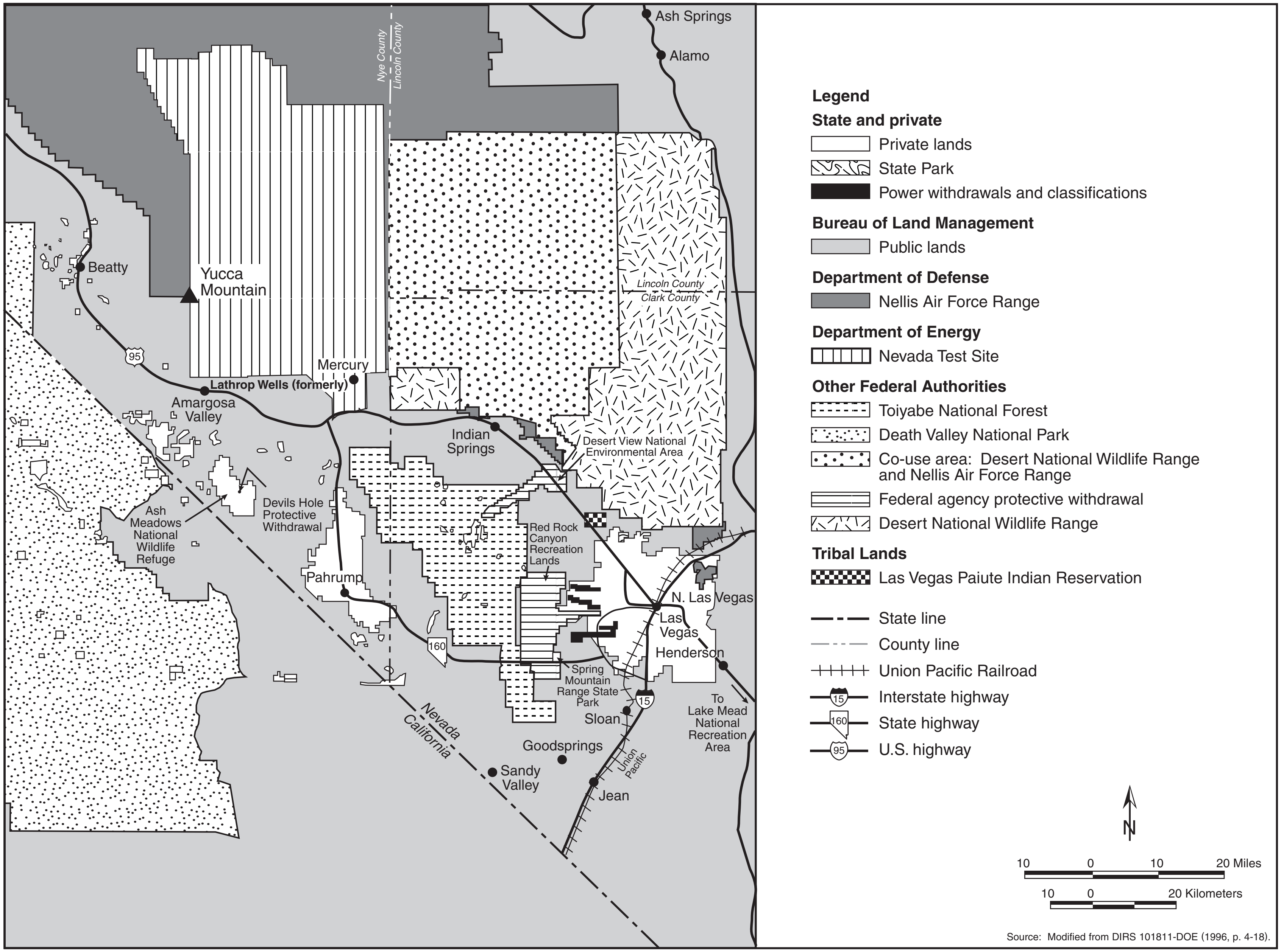


Figure 3-1. Land use and ownership in the Yucca Mountain region.

3.1.1.2 Current Land Use and Ownership at Yucca Mountain

DOE has established land-use agreements to support its site characterization activities at Yucca Mountain. The Yucca Mountain Site Characterization Zone (Figure 3-2) includes DOE, Bureau of Land Management, and Air Force lands.

The Bureau of Land Management granted DOE a right-of-way reservation (N-47748) for Yucca Mountain site characterization activities (DIRS 102218-BLM 1988, all). This reservation comprises 210 square kilometers (52,000 acres). The land in this reservation is open to public use, with the exception of about 20 square kilometers (5,000 acres) near the site of the proposed repository that were withdrawn in 1990 from the mining and mineral leasing laws to protect the physical integrity of the repository block (P.L. Order 6802, "Withdrawal of Public Land to Maintain the Physical Integrity of the Subsurface Environment, Yucca Mountain Project"). The lands in this reservation not withdrawn from the mining and mineral leasing laws contain a number of unpatented mining claims (lode and placer). In addition, there is one patented mining claim surrounded by the reservation. Patented Mining Claim No. 27-83-0002 covers 0.8 square kilometer (200 acres) to mine volcanic cinders used as a raw material in the manufacture of cinderblocks.

The Bureau of Land Management manages surface resources on the Nellis Air Force Range. In 1994, the Bureau granted DOE a right-of-way reservation (N-48602) to use about 75 square kilometers (19,000 acres) of Nellis land for Yucca Mountain site characterization activities (DIRS 102219-BLM 1994, all). This land, which is closed to public access and use, has been studied extensively. Many of the exploratory facilities are on Nellis land.

The Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office have a management agreement that allows the use of about 230 square kilometers (58,000 acres) of Nevada Test Site land for site characterization activities. The Land Facility Use Management Policy under the Memorandum of Agreement with the Nevada Test Site gives the Yucca Mountain Project technical responsibility independent of, but in coordination with, environmental activities at the Nevada Test Site. The Yucca Mountain Project is in compliance with the agreement, which requires it to meet the same environmental requirements that apply to the Nevada Test Site.

3.1.1.3 Potential Repository Land Withdrawal

Nuclear Regulatory Commission initial licensing conditions for a monitored geologic repository (10 CFR Part 60) have been modified under 10 CFR Part 63 to include risk-informed, performance-based environmental regulations. These conditions include a requirement that the lands for which DOE is seeking a repository license be either acquired and under the jurisdiction and control of DOE or be permanently withdrawn and reserved for its use. As noted, portions of the lands being used for site characterization that would be required for the repository are controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office. Because all of these lands are not under permanent DOE control, a land withdrawal would be required.

The procedure for land withdrawal is the method by which the Federal Government places exclusive control over land it owns with a particular agency for a particular purpose. Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Congress can authorize and direct a permanent withdrawal of lands such as those required for the proposed repository at Yucca Mountain. The extent and conditions of the withdrawal would be determined by Congress. The extent of a land withdrawal area is important to the analysis and understanding of the impacts of the Proposed Action. For example, the magnitude of impacts to a member of the public from an accident at an operating repository would be determined in part by the proximity of the land withdrawal boundary to

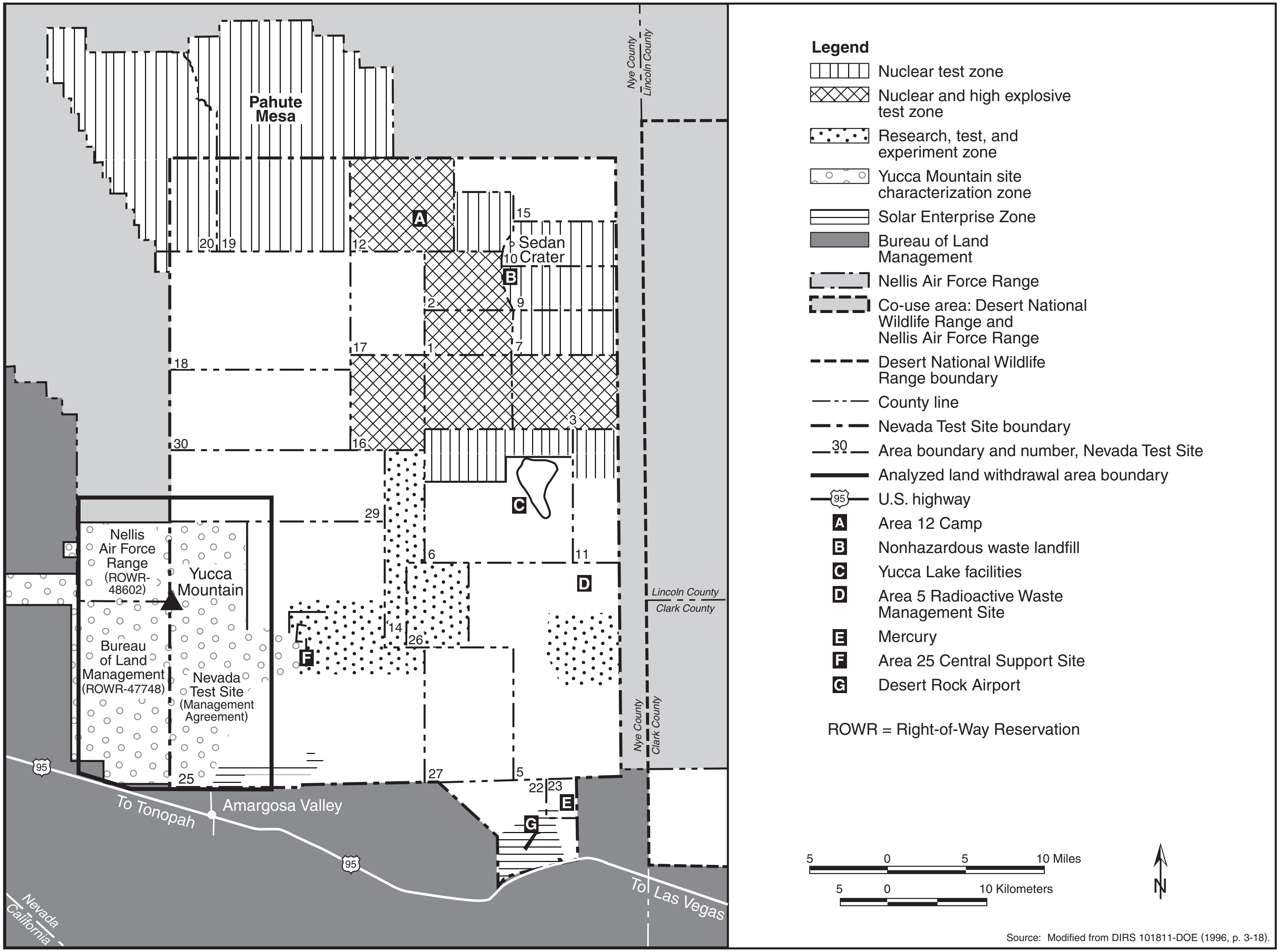


Figure 3-2. Land use and ownership in the analyzed land withdrawal area and vicinity.

the repository operations areas. As a consequence, DOE used a conservative land withdrawal area to extend control toward the closest populated area, the Town of Amargosa Valley, Nevada, thus preventing future encroachment as the basis for analysis in this EIS. The identification of either a restricted or *controlled area* boundary would be defined as part of the licensing process, if there was a determination to proceed with the Yucca Mountain Repository.

Figure 3-2 shows the land withdrawal area analyzed in this EIS that encompasses the current right-of-way reservations for site characterization. This area includes about 600 square kilometers (150,000 acres) of land. The land in this area is currently under the control of the Air Force, DOE, and the Bureau of Land Management (Table 3-4). Approximately 180 square kilometers (45,000 acres) of Bureau of Land Management land in the southwestern portion of the withdrawal area overlaps the taxing district for the unincorporated Town of Amargosa Valley, Nevada. This taxing district, described under Section 18.04.010 of the Nye County Code and Nye County Ordinance 136, encompasses approximately 1,300 square kilometers (320,000 acres). The 180 square kilometers of overlap is Federal land that the Bureau of Land Management administers as public land under a multiple-use classification that the Federal Government has not conveyed to a municipality.

Table 3-4. Current land administration and public accessibility to the analyzed land withdrawal area.[a,b]

Agency	Area (square kilometers)[c]	Current accessibility
DOE (Nevada Test Site)	320	No public access
U.S. Air Force (Nellis Air Force Range)	96	No public access
Bureau of Land Management (public land)	180	Public access
Private land (one patented mining claim)	1	No public access

a. Source: DIRS 153650-YMP (1998, all); DIRS 101521-BLM (1992, all).
b. A description of the area by township, range, and section is available from DOE, Las Vegas, Nevada.
c. To convert square kilometers to square miles, multiply by 0.3861; to convert to acres, multiply by 247.1.

Most of the land controlled by the Bureau of Land Management in the analyzed land withdrawal area is associated with the current right-of-way reservation (N-47748) for Yucca Mountain site characterization activities. This land is open to public use, with the exception of about 20 square kilometers (5,000 acres) near the site of the proposed repository that are withdrawn from the mining and mineral leasing laws and an existing patented mining claim (No. 27-83-0002). The lands open to public use also contain a number of unpatented mining claims (lode and placer). Off-road vehicle use is permitted in these lands. There is a designated utility corridor in the southern portion of these lands.

More detailed descriptions of the land under the control of the Bureau of Land Management in the region of Yucca Mountain are available in the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

3.1.1.4 Native American Treaty Issue

One Native American ethnic group with cultural and historic ties to the Yucca Mountain region is the Western Shoshone. A special concern of the Western Shoshone people is the Ruby Valley Treaty of 1863. The Western Shoshone people maintain that the treaty gives them rights to 97,000 square kilometers (24 million acres) in Nevada, including the Yucca Mountain region (DIRS 102216-Western Shoshone v. United States 1997, all). The legal dispute over the land began in 1946 when the Indian Claims Commission Act gave tribes the right to sue the Federal Government for unkept treaty promises. If a tribe were to win a claim against the Government, the Act specifies that the tribe could receive only a monetary award and not land or other remunerations.

The Western Shoshone people filed a claim in the early 1950s alleging that the Government had taken their land. The Indian Claims Commission found that Western Shoshone title to the Nevada lands had gradually extinguished and set a monetary award as payment for the land. In 1976, the Commission entered its final award to the Western Shoshone people, who dispute the Commission findings and have not accepted the monetary award for the lands in question. They maintain that a settlement has not been reached (the U.S. Treasury is holding these monies in an interest-bearing account) and that Yucca Mountain is on Western Shoshone land. A 1985 U.S. Supreme Court decision (DIRS 148197-United States v. Dann 1985, all) ruled that even though the money has not been distributed, the United States has met its obligations with the Commission's final award and, as a consequence, the aboriginal title to the land had been extinguished.

3.1.2 AIR QUALITY AND CLIMATE

The region of influence for air quality is an area within a radius of about 80 kilometers (50 miles) around the site of the proposed repository and at the boundaries of controlled lands around Yucca Mountain. This region encompasses portions of Esmeralda, Clark, Lincoln, and Nye Counties in Nevada and a portion of Inyo County, California. To determine the air quality and climate for the Yucca Mountain region, DOE site characterization activities have included the monitoring of air quality and meteorological conditions. The Department has monitored the air for gaseous *criteria pollutants* (*carbon monoxide*, nitrogen dioxide, *ozone*, and *sulfur dioxide*) and for *particulate matter*. This section describes the existing air quality and climate at the proposed repository site and in the surrounding region. Sections 3.1.2.1 and 3.1.2.2 describe the air quality and climate, respectively. Unless otherwise noted, the *Environmental Baseline File for Meteorology and Air Quality* (DIRS 102877-CRWMS M&O 1999, all) is the basis for the information provided in this section.

3.1.2.1 Air Quality

Air quality is determined by measuring concentrations of certain pollutants in the atmosphere. The U.S. Environmental Protection Agency designates an area as being *in attainment* for a particular pollutant if *ambient* concentrations of that pollutant are below National *Ambient Air Quality Standards* (Table 3-5). (*Ambient air* is that part of the atmosphere outside buildings to which the general public has access.) The Environmental Protection Agency established the national standards, as directed by the Clean Air Act, to define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). The standards specify the maximum pollutant concentrations and frequencies of occurrence for specific averaging periods.

Areas in violation of one or more of these standards are called *nonattainment areas*. If there are not enough air quality data to determine the status of attainment of a remote or sparsely populated area, the area is listed as *unclassified*. For regulatory purposes, unclassified areas are considered to be in attainment.

Section 176(c)(1) of the Clean Air Act requires Federal agencies to ensure that their actions conform to applicable implementation plans for achieving and maintaining National Ambient Air Quality Standards for criteria pollutants. In addition, this section of the Act assigns primary oversight responsibility to the agencies, not to the Environmental Protection Agency or the States. Specifically, for there to be conformity, a Federal action must not contribute to new violations of standards for ambient air quality, increase the frequency or severity of existing violations, or delay timely attainment of standards in the area of concern (for example, a State or a smaller air quality region). The Environmental Protection Agency general conformity regulations (40 CFR 93, Subpart B) contain guidance for determining if a proposed Federal action would cause emissions to be above certain levels in locations designated as nonattainment or maintenance areas. In this case, a maintenance area is a region that was previously in nonattainment, but which has been redesignated to an attainment area with a requirement to develop a maintenance plan.

Table 3-5. National and Nevada ambient air quality standards.[a]

Pollutant	Primary and Secondary NAAQS,[b] except as noted: Period	Concentration	Highest measured Yucca Mountain concentration[c]	Nevada standards[d]
Sulfur dioxide	Annual[e]	0.03 part per million	0.002	Same
	24-hour[f]	0.14 part per million	0.002	
Sulfur dioxide (secondary)	3-hour[f]	0.5 part per million	0.002	
PM_{10}[g]	Annual[h]	50 micrograms per cubic meter	12	Same
	24-hour[i]	150 micrograms per cubic meter	67	
$PM_{2.5}$[j]	Annual[h]	15 micrograms per cubic meter	N/A[k]	None
	24-hour[l]	65 micrograms per cubic meter	N/A	
Carbon monoxide	8-hour[f]	9 parts per million	0.2	Same[m]
	1-hour[f]	35 parts per million	0.2	Same
Nitrogen dioxide	Annual[e]	0.053 part per million	0.002	Same
Ozone	1-hour[n]	0.12 part per million	0.1	Same
	8-hour[o]	0.08 part per million	N/A	None

a. Sources: 40 CFR 50.4 through 50.11; Nevada Administrative Code 445B.391.
b. NAAQS = National Ambient Air Quality Standard.
c. Units correspond to the units listed in the concentration column.
d. Nevada Administrative Code 445B.391.
e. Average not to be exceeded in the period shown.
f. Average not to be exceeded more than once in a calendar year.
g. PM_{10} = particulate matter with a diameter less than 10 micrometers (0.0004 inch). Until the revised State Implementation Plan is approved, 40 CFR 50.6 applies; then 40 CFR 50.7 would apply.
h. Expected annual arithmetic mean should be less than value shown.
i. Number of days per calendar year exceeding this value should be less than 1. Under 40 CFR 50.7, 99th-percentile value should be less than value shown.
j. $PM_{2.5}$ = particulate matter with a diameter less than 2.5 micrometers (0.0001 inch). Standard has not been implemented.
k. N/A = not available; no monitoring data has been collected since the new standard was implemented.
l. 98th-percentile value should be less than value shown.
m. The Nevada ambient air quality standard for carbon monoxide is 9 parts per million at less than 1,500 meters (4,900 feet) above mean sea level and 6 parts per million at or above 1,500 meters; Nevada Administrative Code 445B.31.
n. This standard was replaced in 1998 by 40 CFR 50.10 for all air quality regions of interest.
o. Standard promulgated in 1997, but not yet implemented due to court challenges. Three-year average of the fourth-highest monitored daily maximum 8-hour average concentration.

The quality of the air at the site of the proposed repository and the surrounding parts of the Nevada Test Site, Nellis Air Force Range (including southwestern Lincoln County), southwestern Esmeralda County, and southern Nye County is unclassified because there are limited air quality data (40 CFR 81.329). Data collected at the site indicate the air quality is within applicable standards. Portions of Clark County in the air quality region of influence are in attainment with the National Ambient Air Quality Standards. Inyo County, California, is in attainment with national and California ambient air quality standards for carbon monoxide, nitrogen dioxide, and sulfur dioxide. It is in attainment with the national *PM_{10} standard*, but in nonattainment with the more restrictive California standard (DIRS 103161-CEPA 1998, pp. H6 to H35). Outside the repository air quality region of influence, most of Nevada is unclassified and therefore in attainment. There are Nevada exceptions; Reno and Las Vegas are both in nonattainment for carbon monoxide and PM_{10} and the Lake Tahoe basin is in nonattainment for carbon monoxide. In addition, the Reno area is in nonattainment for ozone. Section 3.2.2 contains additional air quality information.

Air quality in attainment areas is controlled under the Prevention of Significant Deterioration program of the Clean Air Act, with the goal of preventing significant deterioration of existing air quality. Under the Prevention of Significant Deterioration provisions, Congress established a land classification scheme for areas of the country with air quality better than the National Ambient Air Quality Standards. Class I allows very little deterioration of air quality; Class II allows moderate deterioration; and Class III allows more deterioration; but in all cases the pollution concentrations shall not violate any of the National

Ambient Air Quality Standards. Congress designated certain areas as mandatory Class I, which precludes redesignation to a less restrictive class, to acknowledge the value of maintaining these areas in relatively pristine condition. Congress also protected other nationally important lands by originally designating them as Class II and restricting redesignation to Class I only.

All other areas were initially classified as Class II, and can be redesignated as either Class I or Class III. In the region of influence, all areas are designated as Class II. There are no Class I areas, although one area, the Death Valley National Park, is a national monument and a protected Class II area that could be redesignated as Class I (DIRS 148117-EPA 1998, all; DIRS 148119-EPA 1997, all). It is about 35 kilometers (22 miles) southwest of Yucca Mountain.

The construction and operation of a facility in an attainment area could be subject to the requirements of the Prevention of Significant Deterioration program if the facility received a classification as a major source of air pollutants. At present, the proposed repository site and the Nevada Test Site have no sources subject to those requirements (DIRS 101811-DOE 1996, p. 4-146).

As part of Yucca Mountain site characterization, DOE obtained an air quality operating permit from the State of Nevada (DIRS 104920-Del Porto 1996, all). The permit places specific operating conditions on various systems that DOE uses during site characterization activities. These conditions include limiting the emission of criteria pollutants, defining the number of hours a day and a year a system is allowed to operate, and determining the testing, monitoring, and recordkeeping required for the system.

In 1997, the Environmental Protection Agency issued new National Ambient Air Quality Standards for ozone and particulate matter. The new standard for particulate matter (40 CFR 50.7) includes fine particles in the respirable range with diameters smaller than 2.5 micrometers (see Table 3-5). The implementation of this new standard applies to all areas, but initial monitoring will focus on urban areas because (1) this pollutant comes primarily from combustion (auto exhaust, etc.) rather than *fugitive dust* sources (windblown dust, etc.) and (2) the first priority for monitoring programs is the assessment of densely populated areas. The new (1997) standard for ozone included revoking the 1-hour ozone standard for all counties in the United States with no current measured violations, including all of Nevada and the region around Yucca Mountain, and replacing it with a new 8-hour ozone standard. The new particulate and ozone standards were challenged in court and subsequently overturned by a Federal appeals court (DIRS 148090-American Trucking Associations v. U.S. Environmental Protection Agency 1999, all). As a result, the Environmental Protection Agency reinstated the 1-hour ozone standard in July 2000. However, early in 2001 the U.S. Supreme Court upheld the ability of the Environmental Protection Agency to set national air quality standards (DIRS 156704-Whitman v. American Trucking Associations 2001, all). Following its ruling, the Supreme Court remanded the case back to the appeals court to resolve all outstanding issues in light of its opinion. Implementation of the standards is delayed pending resolution of implementation details and some additional legal issues.

In 1989, DOE began monitoring particulate matter at the site of the proposed repository as part of site characterization activities and later as part of the Nevada Air Quality operating permit requirements. Concentration levels of inhalable particles smaller than 10 micrometers in diameter have been well below applicable National Ambient Air Quality Standards, with annual average concentrations 20 to 25 percent of the standard (see Table 3-5).

From October 1991 through September 1995, DOE monitored the site of the proposed repository for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) as part of site characterization. The concentration levels of each pollutant were well below the applicable National Ambient Air Quality Standards (see Table 3-5). In fact, concentrations of carbon monoxide and sulfur dioxide were not detectable during the entire monitoring period. Nitrogen dioxide was detected occasionally at concentrations of a few parts per billion (around 0.002 part per million) by volume, probably from nearby vehicle exhausts, about 4 percent of the applicable annual average standard (see Table 3-5). Ozone was the only criteria pollutant routinely detected; the maximum hourly concentrations were 0.081 to 0.096 part per million, which is 67 to 80 percent of the 1-hour regulatory standard. The source of the ozone has not been determined, but could be urban areas in southern California.

3.1.2.2 Climate

The Yucca Mountain region has a relatively arid climate, with annual precipitation totals ranging between approximately 10 and 25 centimeters (4 and 10 inches) per year (DIRS 101779-DOE 1998, Volume 1, p. 2-29). Precipitation at a given location depends on nearby topographic features. The winter season is mild, with some periods of below freezing temperatures. Occasional periods of persistent rain have produced more than 5 centimeters (2 inches) of rainfall in daily periods. The summer season is typically hot and dry, with occasional periods of monsoon thunderstorms producing locally large amounts of rain. Storms can produce more than 2.5 centimeters (1 inch) of rain in a matter of hours.

Mean nighttime and daytime air temperatures typically range from 22°C to 34°C (72°F to 93°F) in the summer and from 2°C to 10.5°C (34°F to 51°F) in the winter (DIRS 100117-CRWMS M&O 1997, pp. A-1 to A-16). Temperature extremes range from -15°C to 45°C (5°F to 113°F). On average, the daily range in temperature change is about 10°C (18°F). Higher elevations are cooler, though the coldest areas can be in canyons and washes to which heavy cold air flows at night. Relative humidity levels range from about 10 percent on summer afternoons to about 50 percent on winter mornings and to near 100 percent during precipitation events.

In the valleys, airflow is channeled by local topography, particularly at night during stable conditions (DIRS 100117-CRWMS M&O 1997, p. 4-13 to 4-16). With the exception of the nearby confining terrain, which includes washes and small canyons on the east side of Yucca Mountain, local wind patterns have a strong daily cycle of daytime winds from the south and nighttime winds from the north. Confined areas also have daily cycles, but the wind directions are along terrain axes, typically upslope in the daytime and downslope at night. Wind direction can also vary with height. As shown in Figure 3-3, the winds at a height of 60 meters (200 feet) show a strong north-south flow up and down the valley. The winds at 10 meters (33 feet) show a strong southerly flow, but at night the wind pattern reflects more of the drainage flow downslope from Yucca Mountain. Hourly average wind speeds are usually greater than 1.8 meters a second (4 miles an hour), indicating few calm periods. Over the entire monitoring network, the average wind speed ranges from 2.5 to 4.4 meters a second (5.6 to 9.8 miles an hour); the fastest 1-minute wind speeds range from 19 to 33 meters a second (42 to 74 miles an hour); and the peak gusts range from 26 to 38 meters a second (59 to 86 miles an hour). The highest wind speeds typically occur on exposed ridges.

Severe weather can occur in the region, usually in the form of summer thunderstorms. These storms can generate an abundant amount of lightning, strong winds, and heavy and rapid precipitation. Tornadoes can occur, though they are not a substantial threat in the region; four have been recorded within 240 kilometers (150 miles) of the site of the proposed repository during the past 53 years, and one occurred in 1987 in the Amargosa Desert about 50 kilometers (30 miles) south of the site (DIRS 100117-CRWMS M&O 1997, p. 4-26).

Paleoclimatology. Climate studies and analyses pursued as part of the Yucca Mountain project have also included paleoclimatology, which is the study of ancient climates. These studies looked at time scales as large as hundreds of millennia. The primary assumption associated with paleoclimatology efforts is that climate is cyclical so that past climates provide insight into potential future climates (DIRS 151945-CRWMS M&O 2000, p. 6.4-2). The efforts have incorporated studies of the Earth's orbital and global circulation parameters and how those parameters have affected ancient climates in the Yucca Mountain region. Orbital parameters include theories that the shape of the Earth's orbit and the "wobble"

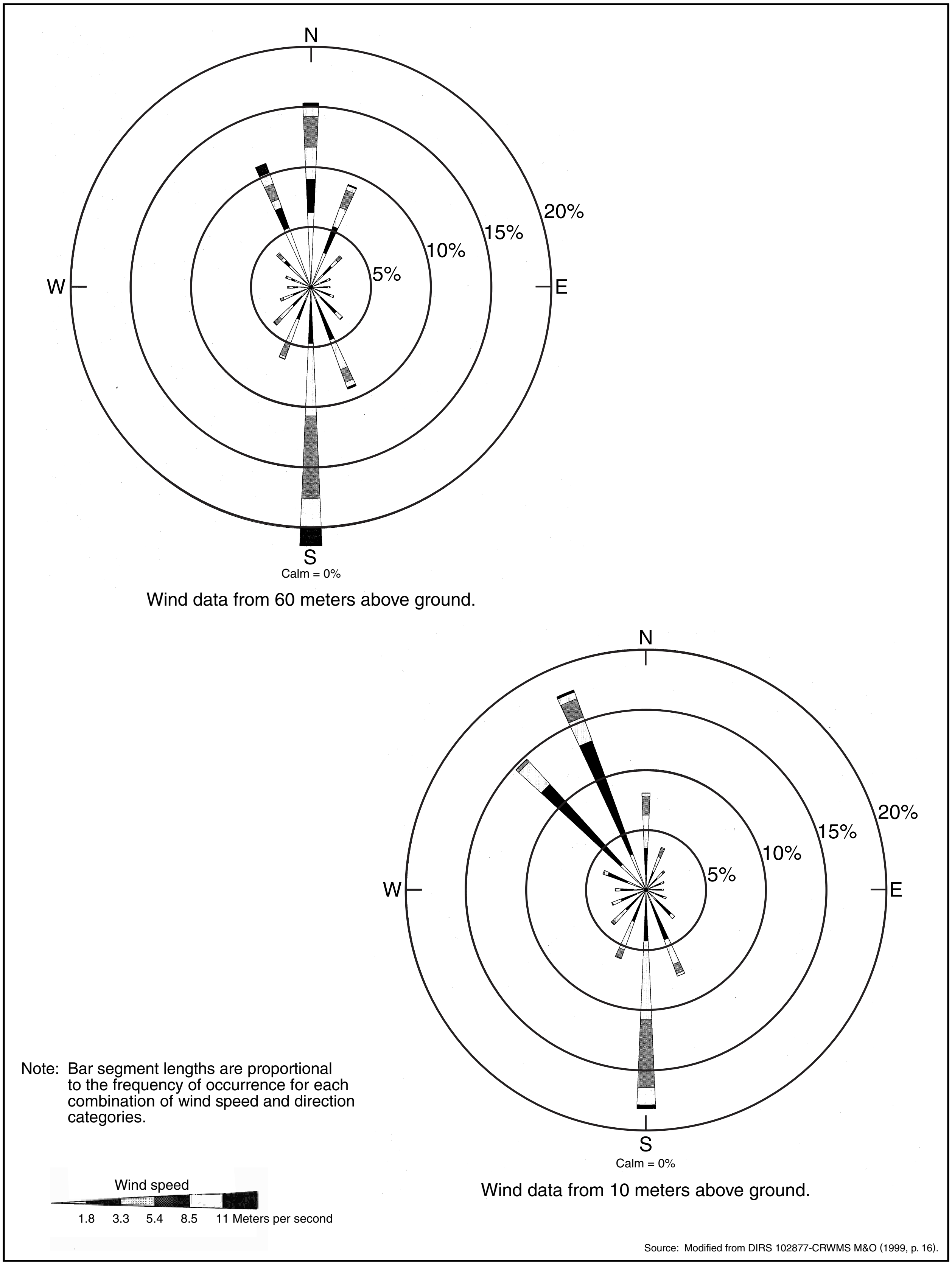


Figure 3-3. Wind rose plots for 10 and 60 meters (33 and 200 feet) above ground in the proposed repository facilities vicinity.

in its axial spin change in cycles that repeat over tens and hundreds of millennia (DIRS 151945-CRWMS M&O 2000, p. 6.3-4). Correlations have been made between these global position changes and long duration traces, or evidence, of paleoclimate conditions in the region. Two of the primary sources of this evidence are calcite deposited on the walls of rock fractures at Devils Hole in Nevada and lake deposits at the historic Owens Lake location in California. In these examples, analysis of residues left behind has provided insights into climate conditions as far back as 600,000 to 850,000 years ago (DIRS 151945-CRWMS M&O 2000, pp. 6.3-9 and 6.3-12).

Climate regimes believed to have existed in Yucca Mountain's past, and therefore that should occur in its future, have been grouped into the following categories: (1) a warm and dry, modern-like interglacial climate; (2) a warm and wet monsoon climate; (3) an intermediate glacial transition climate; and (4) glacial periods (DIRS 151945-CRWMS M&O 2000, pp. 6.4-11 and 6.4-17). The driest of these climate groupings is the modern-like interglacial climate and (as indicated by its name) represents the climate currently being experienced at Yucca Mountain. Characteristics of these climate regimes and postulated future durations are included as input parameters to the long-term performance assessment modeling performed for the site (DIRS 153246-CRWMS M&O 2000, pp. 3-38 to 3-42).

3.1.3 GEOLOGY

DOE has studied the existing physiographic setting (characteristic landforms), *stratigraphy* (rock strata), and geologic structure (structural features resulting from rock deformations) at Yucca Mountain and in the surrounding region. These studies have yielded detailed information about the surface and subsurface features in the region. This section describes the region of influence for geology, which includes the baseline conditions of the region's geology as well as the specific geology of Yucca Mountain. DOE investigated seismicity (*earthquake* activity) in the Yucca Mountain region; the investigations focused on understanding the Quaternary history of movement on faults in the region and the historic record of earthquake activity. The Department also investigated volcanoes in the Yucca Mountain region to assess the potential for volcanism to result in adverse effects to a repository. In addition, DOE considered the possibility that there might be minerals and energy resources at or near the site of the proposed repository.

3.1.3.1 Physiography (Characteristic Landforms)

Yucca Mountain is in the southern part of the *Great Basin* subprovince of the Basin and Range Physiographic Province (Figure 3-4), a region characterized by generally north-trending, linear mountain ranges separated by intervening valleys (basins) (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). The Great Basin encompasses nearly all of Nevada plus parts of Utah, Idaho, Oregon, and California. Mountain ranges of the Great Basin, including Yucca Mountain, are mostly tilted, fault-bounded crustal blocks that are as much as 80 kilometers (50 miles) long and 8 to 24 kilometers (5 to 15 miles) wide. Ranges typically rise from 300 to 1,500 meters (1,000 to 4,900 feet) above the adjacent valley floors and occupy 40 to 50 percent of the total land area (DIRS 151945-CRWMS M&O 2000, pp. 4.4-1 and 4.4-2).

Valleys between the mountain ranges are filled with alluvial sediments (deposits of sand, mud, and other such materials formed by flowing water) from the adjacent ranges. Many valleys are called *closed basins* because they, like the Great Basin on a regional scale, lack a drainage outlet (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). Water and sediment from adjacent ranges become trapped and move to the lowest part of such valleys to form a *playa*, a flat area that is largely vegetation-free owing to high salinity, which results from evaporation of the water. Valleys with drainage outlets have intermittent stream channels that carry eroded sediment to lower drainage areas.

The present landscape, distinguished by the broad series of elongated mountain ranges alternating with parallel valleys, is the result of past episodes of faulting that elevated the ranges above the adjacent valleys. Section 3.1.3.2 addresses such faulting. Yucca Mountain is an irregularly shaped volcanic

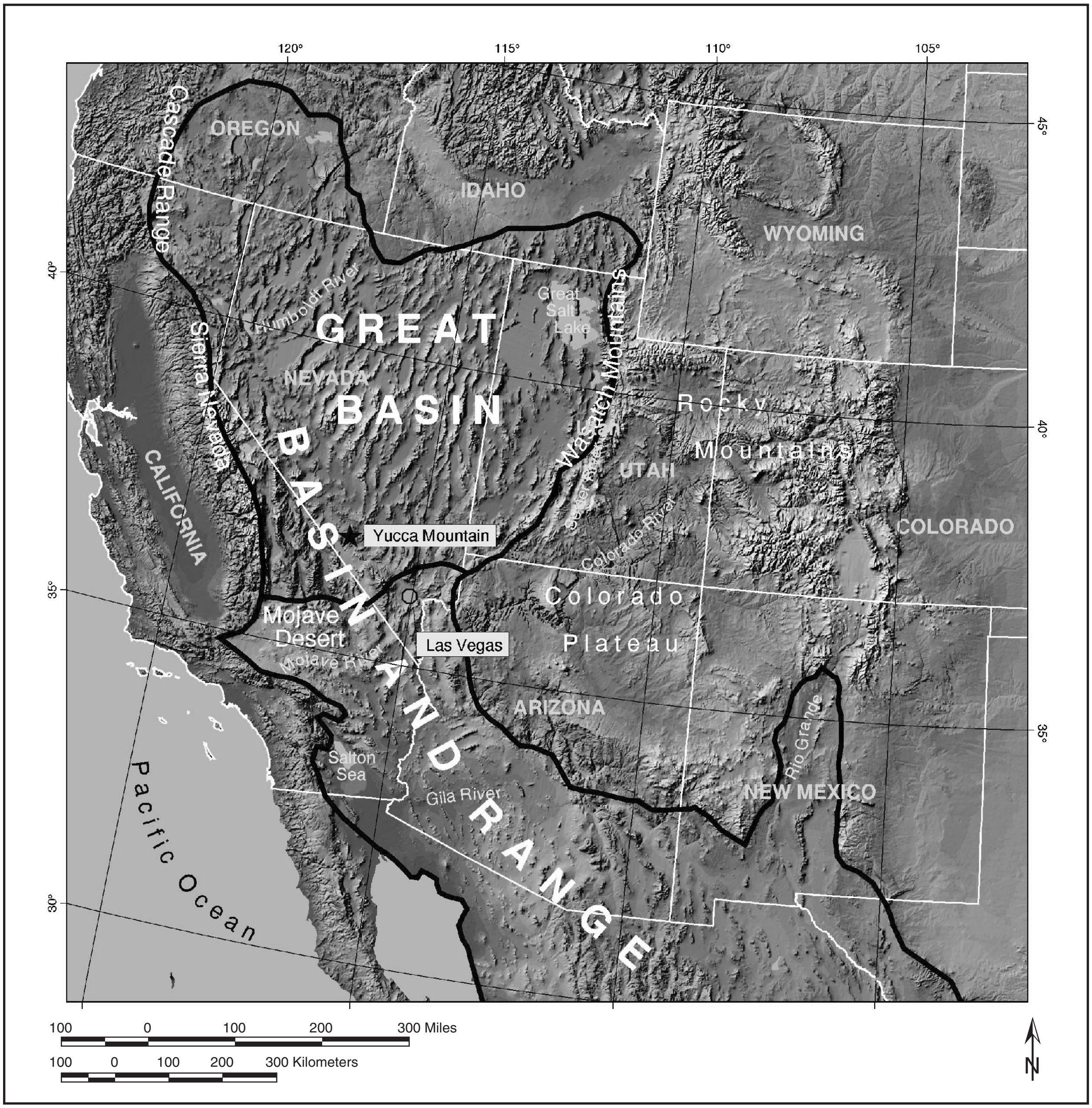


Figure 3-4. Basin and Range Physiographic Province and Great Basin Subprovince.

upland, 6 to 10 kilometers (4 to 6 miles) wide and 35 kilometers (22 miles) long (DIRS 151945-CRWMS M&O 2000, pp. 2.2-1 and 4.4). This mountain is part of a volcanic plateau formed between about 14 million and 11.5 million years ago (DIRS 100075-Sawyer et al. 1994, p. 1304) known as the Southwestern Nevada volcanic field. Although Yucca Mountain is a product of both volcanic activity and faulting, the region exhibits evidence of a complex history of *deformation* associated with past interactions of crustal segments (plates) (DIRS 151945-CRWMS M&O 2000, p. 4.2-1). Geologic relations indicate that many of the current features and the landscape in the Yucca Mountain region formed between 12.7 million and 11.7 million years ago (DIRS 151945-CRWMS M&O 2000, p. 4.4-2). Remnants of the Timber Mountain caldera (one of the centers of the southwestern Nevada volcanic field from which most of the volcanic rocks on the surface of Yucca Mountain were erupted) and other calderas are north of Yucca Mountain (see Figure 3-5).

Main Index

Vol 1 Index

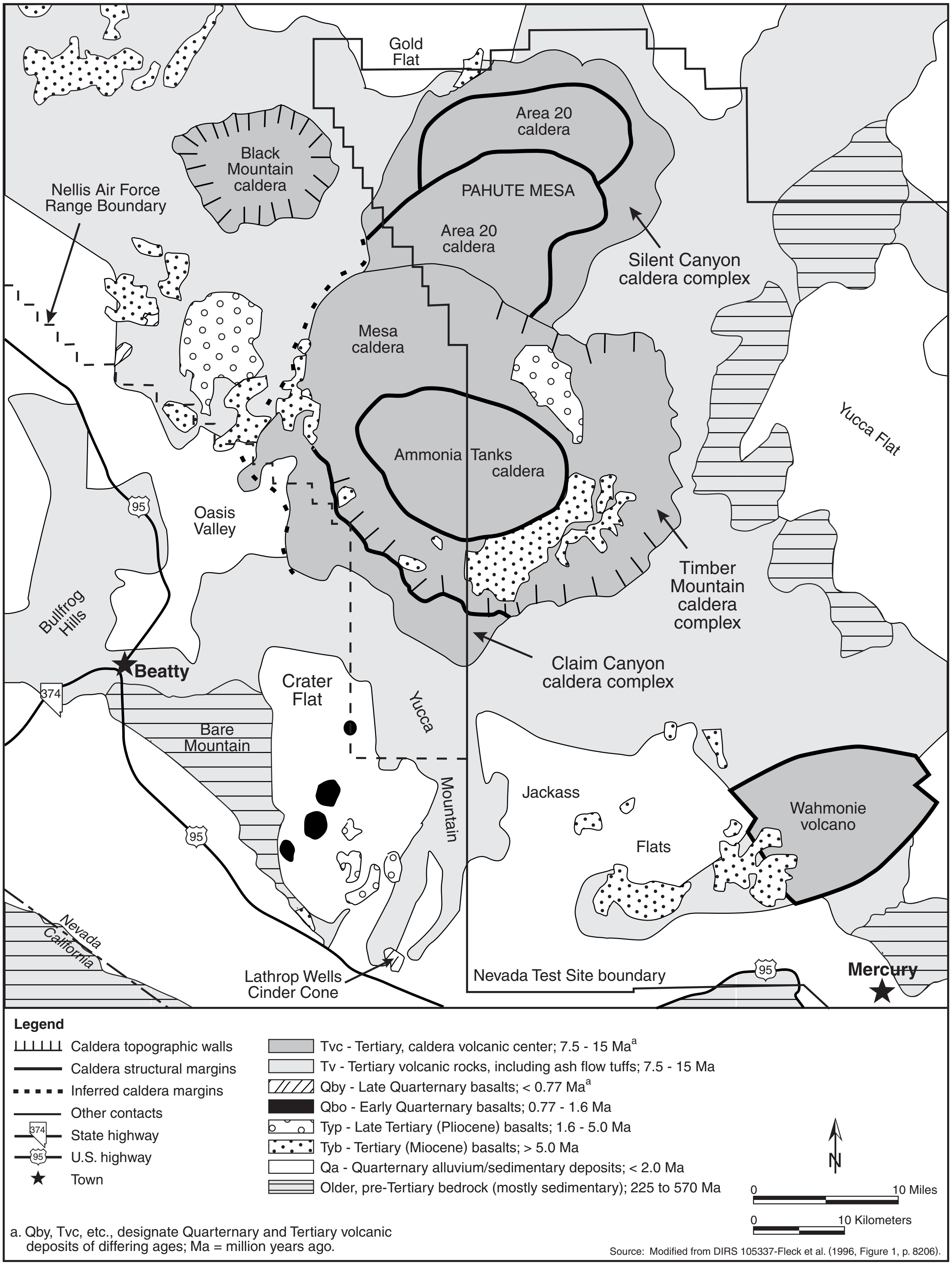


Figure 3-5. Simplified geologic map showing calderas of the southwest Nevada volcanic field in the Yucca Mountain vicinity.

Almost without exception, west-facing slopes at Yucca Mountain are steep and east-facing slopes are gentle, which expresses the underlying geologic structure (see Section 3.1.3.2). Small valleys eroded in the mountain are narrow, V-shaped drainages that flatten and broaden near the mountain base. The crest of Yucca Mountain reaches elevations from 1,500 meters (4,900 feet) to 1,900 meters (6,300 feet) above sea level. The bottoms of the adjacent valleys are approximately 650 meters (2,100 feet) lower (DIRS 151945-CRWMS M&O 2000, p. 4.4-4).

Yucca Mountain is bordered on the north by Pinnacles Ridge and *Beatty Wash*, on the west by *Crater Flat*, on the south by the Amargosa Desert, and on the east by the Calico Hills and by *Jackass Flats*, which contains *Fortymile Wash* (Figure 3-6). Beatty Wash is one of the largest tributaries of the Amargosa River and drains the region north and west of Pinnacles Ridge, including the northern end of Yucca Mountain.

Crater Flat (Figure 3-6) is an oval-shaped valley between Yucca Mountain and *Bare Mountain*. It contains four prominent volcanic cinder cones and related lava flows that rise above the valley floor. Crater Flat drains to the Amargosa River through a gap in the southern end of the basin.

Jackass Flats is an oval-shaped valley east of Yucca Mountain bordered by Yucca, Shoshone, Skull, and Little Skull Mountains (Figure 3-6). It drains southward to the *Amargosa River*. *Fortymile Wash* is the most prominent drainage through Jackass Flats to the Amargosa River.

Site Stratigraphy and Lithology

The exposed stratigraphic section at Yucca Mountain is dominated by mid-Tertiary volcanic ash-flow and ash-fall deposits with minor lava flows and reworked materials. These deposits originated in the calderas shown in Figure 3-5. Regionally, the thick series of volcanic rocks that form Yucca Mountain overlies *Paleozoic* sedimentary rocks that are largely of marine origin. The volcanic rocks, in turn, are covered in many areas by a variety of late Tertiary and Quaternary surficial deposits (DIRS 151945-CRWMS M&O 2000, p. 4.5-1). The stratigraphic section is summarized in Table 3-6, which depicts rock assemblages according to the geologic age during which they were deposited. The stratigraphic sequence of the Yucca Mountain area consists, from oldest to youngest, of Pre-Cenozoic (that is, Paleozoic and Precambrian) sedimentary and metasedimentary (sedimentary rocks that have been altered by metamorphism), mid-Tertiary siliceous (rich in silica) volcanic rocks, Tertiary to Quaternary basalts, and late Tertiary to late Quaternary surficial deposits.

Only Tertiary and younger rocks are exposed at Yucca Mountain (DIRS 151945-CRWMS M&O 2000, p. 4.5-1). Parts of the older (Pre-Cenozoic) rock assemblages described in Table 3-6 are exposed at Bare Mountain, the Calico Hills, and the Striped Hills, to the east, northeast, and southeast of Yucca Mountain, respectively (see Figure 3-6) (DIRS 151945-CRWMS M&O 2000, Figures 4.2-3 to 4.2-6, pp. F4.2-3 to F4.2-6). Many of these older rocks are widespread in the Great Basin where their cumulative thickness is thousands of feet. Detailed information about their characteristics is lacking at Yucca Mountain because only one *borehole*, about 2 kilometers (1.2 miles) east of Yucca Mountain, has penetrated these rocks. Paleozoic carbonate rocks were penetrated in this borehole at a depth of about 1,250 meters (4,100 feet) (DIRS 102046-Carr et al. 1986, p. 5-5). Paleozoic carbonate rocks form important aquifers in southern Nevada (DIRS 101167-Winograd and Thordarson 1975, all).

Table 3-7 lists the principal mid-Tertiary volcanic stratigraphic units mapped at the surface, encountered in boreholes, and examined in the Exploratory Studies Facility that have been a major focus of site characterization investigations. The proposed repository and access to it would be entirely in the Paintbrush Group, so investigations have focused particularly on the formations in that stratigraphic unit. Detailed descriptions of the volcanic stratigraphic units are in the Yucca Mountain Project Stratigraphic Compendium (DIRS 101535-CRWMS M&O 1996, all). The following paragraphs provide a general

Table 3-6. Highly generalized stratigraphy summary for the Yucca Mountain region.[a]

Geologic age designation	Major rock types (lithologies)
Cenozoic Era	
Quaternary Period (< 1.6 Ma)[b]	Alluvium; basalt
Tertiary Period (< 65 - 1.6 Ma)	Silicic ash-flow tuffs; minor basalts. Predominantly volcanic rocks of the southwestern Nevada volcanic field (includes Topopah Spring Tuff, host rock for the potential repository). Table 3-7 lists major Tertiary volcanic formations at Yucca Mountain.
Mesozoic Era (240 - 65 Ma)	No rocks of this age found in Yucca Mountain region.
Paleozoic Era (570 - 240 Ma)	Three major lithologic groups (lithosomes) predominate: a lower (older) carbonate (limestone, dolomite) lithosome deposited during the Cambrian through Devonian Periods (see Figure 3-17), a middle fine-grained clastic lithosome (shale, sandstone) formed during the Mississippian Period, and an upper (younger) carbonate lithosome formed during the Pennsylvanian and Permian Periods.
Precambrian Era (> 570 Ma)	Quartzite, conglomerates, shale, limestone, and dolomite that overlie older igneous and metamorphic rocks that form the crystalline "basement."

a. Source: Adapted from DIRS 151945-CRWMS M&O (2000, pp. 4.2-3 to 4.2-20).
b. Ma = approximate years ago in millions.

summary based on the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, pp. 4.5-1 to 4.5-34).

The bulk of the volcanic sequence consists of tuffs. Volcanic rocks known as ash-flow tuffs (or *pyroclastic* flow deposits) form when a hot mixture of volcanic gas and ash violently erupts and flows.

As the ash settles, it is subjected to various degrees of compaction and fusion depending on temperature and pressure conditions. If the temperature is high enough, glass and pumice fragments are compressed and fused to produce welded tuff (a hard, brick-like rock with very little open pore space in the rock *matrix*). Nonwelded tuffs, compacted and consolidated at lower temperatures, are less dense and brittle and generally have greater porosity. Ash-fall tuffs are formed from ash that cooled before settling on the ground surface, and bedded tuffs are composed of ash that has been reworked by stream action. All of these are found in the volcanic assemblage at Yucca Mountain.

In general, characterization of the various volcanic units is based on changes in depositional features, the development of zones of welding and devitrification (crystallization of glassy material), and the development of alteration products in some rocks. Mineral and chemical composition and properties such as density and porosity also have been used in distinguishing some units. Most of the formations listed in Table 3-7 contain phenocrysts (mineral grains distinctly larger than the surrounding rock matrix) and lithic clasts (rock fragments), have some part that is at least partially welded, and typically have some part that has devitrified during cooling of the deposit. In addition, the vitric (glassy) parts of many formations have been partly altered to clay and *zeolite* minerals, and all the rocks have developed various amounts of fractures, some of which contain secondary mineral fillings.

Lithophysal cavities are prominent features in some units, notably in the Tiva Canyon and Topopah Spring Tuffs, where they range from 1 to 50 centimeters (0.4 to 20 inches) in diameter and are a basis for the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

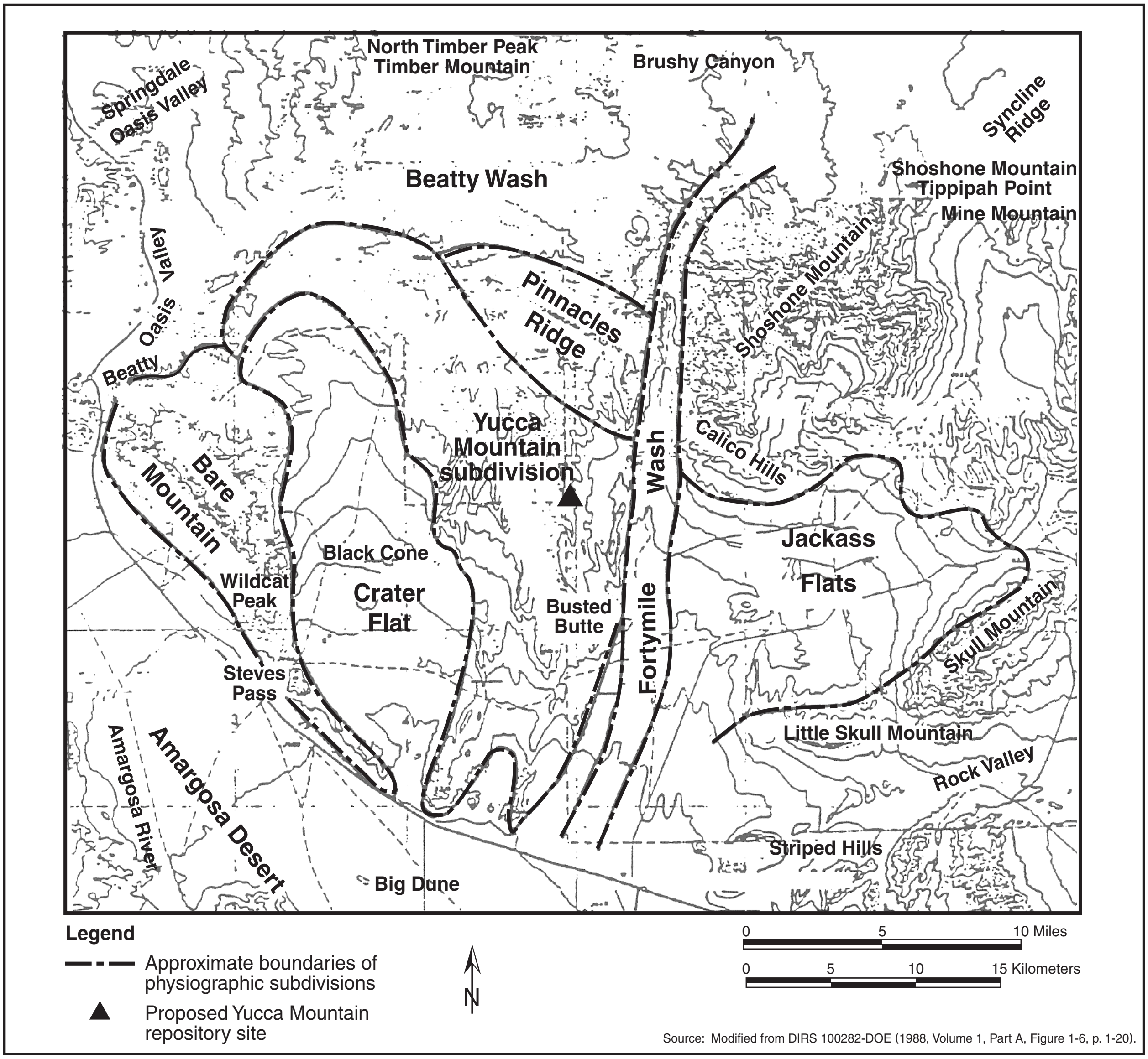


Figure 3-6. Physiographic subdivisions in the Yucca Mountain vicinity.

Although welded tuffs dominate the volcanic sequence, bedded tuffs are present in the Paintbrush Group and in some older parts of the sequence (DIRS 151945-CRWMS M&O 2000, Figures 4.5-3 and 4.5-4, pp. F4.5-3 to F4.5-4). Joints and fractures are common in the welded tuffs, producing much greater bulk permeabilities than those of the nonwelded and bedded tuffs (DIRS 151945-CRWMS M&O 2000, p. 4.10-6). This is an important distinction with regard to investigation of hydrologic conditions.

Some parts of the volcanic formations contain secondary mineral products created by alteration of the original materials after their original deposition and consolidation. Some alteration has resulted from reactions with groundwater, and the types of new mineral substances found can differ based on occurrence below or above the water table. Alteration products such as clay minerals and zeolites occur in several parts of the volcanic sequence; in some places, in-filling with zeolites has reduced the porosity and thus affected hydrologic properties. In most of the formations, contacts between vitric and devitrified layers are commonly marked by an interval containing clay or zeolite alteration minerals. A notable example is the interval, as much as several meters thick, where glassy rock at the base of the Topopah

Table 3-7. Tertiary volcanic rock sequence at Yucca Mountain.[a]

Name	Age (millions of years)[b]	Thickness (meters)[c]	Characteristics
Timber Mountain Group			
• Ammonia Tanks Tuff	11.5	Up to 215	Welded to nonwelded rhyolite tuff; exposed in southern Crater Flat.
• Rainier Mesa Tuff	11.6	< 30 - 240	Nonwelded to moderately welded vitric to devitrified tuff exposed locally along downthrown sides of large normal faults.
Post-Tiva Canyon, pre-Rainier Mesa Tuffs	12.5	0 - 61	Pyroclastic flows and fallout tephra deposits in subsurface along east flank of Yucca Mountain.
Paintbrush Group			Four formations (below) interlayered locally with lava flows and reworked volcanic deposits.
• Tiva Canyon Tuff	12.7	< 50 - 175	Crystal-rich to crystal-poor densely welded rhyolite tuff that forms most rock at surface of Yucca Mountain.
• Yucca Mountain Tuff	--[d]	0 - 45	Mostly nonwelded tuff but is partially to densely welded where it thickens to north and west.
• Pah Canyon Tuff	--	0 - 70	Northward-thickening nonwelded to moderately welded tuff with pumice fragments.
• Topopah Spring Tuff	12.8	Up to 380	Rhyolite tuff divided into upper crystal-rich member and lower crystal-poor member. Each member contains variations in lithophysal content, zones of crystallization, and fracture density. Glassy unit (vitrophyre) present at the base. Proposed host for repository.
Calico Hills Formation	12.9	15 - 460	Northward-thickening series of pyroclastic flows, fallout deposits, lavas, and basal sandstone; abundant zeolites except where entire formation is vitric in southwest part of central block of Yucca Mountain.
Crater Flat Group			Pyroclastic flows and interbedded tuffs of rhyolitic composition distinguished by abundance of quartz and biotite.
• Prow Pass Tuff	13.1	60 - 228	Sequence of variably welded pyroclastic deposits.
• Bullfrog Tuff	13.3	76 - 275	Partially welded, zeolitic upper and lower parts separated by a central densely welded tuff.
• Tram Tuff	13.5	60 - 396	Lower lithic-rich unit overlain by upper lithic-poor unit.
Lithic Ridge Tuff	13.9	185 - 304	Southward thickening wedge of welded and nonwelded pyroclastic flows and interbedded tuff extensively altered to clays and zeolites.
Pre-Lithic Ridge	+14.0	45 - 350	Mostly altered pyroclastic flows, lavas, and bedded tuff of rhyolitic composition.

a. Modified from DIRS 151945-CRWMS M&O (2000, pp. 4.5-19 to 4.5-33).
b. Source: DIRS 151945-CRWMS M&O (2000, Table 4.2-3, p. T4.2-3).
c. To convert meters to feet, multiply by 3.208.
d. -- = no absolute dates.

the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

Spring Tuff (the basal *vitrophyre*) is in contact with the overlying nonlithophysal zone; this interval of alteration occurs in most boreholes in the vicinity of the proposed site (DIRS 151945-CRWMS M&O 2000, p. 4.5-11). Subtle differences in geochemical conditions are believed to have given rise locally over short distances to some unusual zeolites. One in particular is the fibrous zeolite *erionite*, which is a potential human health hazard (see Section 3.1.8.3). Data from rock samples show that in the potential repository horizon erionite, if it occurs, is either in the altered zone immediately above the Topopah Spring lower vitrophyre or in the moderately welded zone underlying this vitrophyre. It has also been identified in the lower Tiva Canyon Tuff (DIRS 101779-DOE 1998, Volume 1, p. 2-25).

Figure 3-7 is a geologic map that shows the surficial distribution of Tertiary volcanic units and younger surficial deposits in the vicinity of the proposed site. Figure 3-8 is a vertical cross-section through the southern part of this area that shows the subsurface expression of the mapped units, including structural aspects (east-dipping rock units and predominantly west-dipping normal faults). Examples of Tertiary units include the lava flows that cap Skull and Little Skull Mountains at the south and southeast margins of Jackass Flats, a *basalt* ridge that forms the southern boundary of Crater Flat, and a basaltic dike dated at 10 million years (DIRS 151945-CRWMS M&O 2000, p. 4.5-33) that intrudes in the northern part of the Solitario Canyon fault, which bounds the west flank of Yucca Mountain. Volcanic rocks younger than the Tertiary units occur locally at and in the Yucca Mountain vicinity but are of limited extent (Figure 3-5). They represent low-volume eruptions typically consisting of a single main cone surrounded by a small field of basalt flows. A north-trending series of cinder cones and lava flows on the southeast side of Crater Flat has been dated at 3.7 million years, and in the center of Crater Flat a series of four northeast-trending cinder cones (Qbo in Figure 3-5) has been dated at about 1 million years. The youngest basaltic center is the Lathrop Wells center, which is a single cone estimated to be 80,000 years old, with several different age dating methods putting the age between 70,000 and 90,000 years (DIRS 151945-CRWMS M&O 2000, p. 12.2-5). Some authors, however, cite evidence for *polycyclic volcanism*, suggesting a significant time interval between the emplacement of the Lathrop Wells *scoria* deposits.

The youngest stratigraphic units at Yucca Mountain are the predominantly unconsolidated surficial deposits of late Tertiary and Quaternary age. They are shown in Figure 3-7 as *alluvium* (material such as sand, silt, clay, pebbles, cobbles, or even boulders deposited on land by water) and *colluvium* (loose earth material that has accumulated at the base of a hill through the action of gravity) but have been classified in more detail as stream (alluvial) deposits, hillslope (colluvial) deposits, spring deposits, and windblown (eolian) deposits (DIRS 151945-CRWMS M&O 2000, pp. 4.4-10 to 4.4-21). Most Quaternary units exposed at the surface were deposited during the last 100,000 years (DIRS 101779-DOE 1998, Volume 1, p. 2-26). The bulk of these consist of alluvium deposited by intermittent streams that transported rock debris from hillslopes to adjacent washes and valleys.

Selection of Repository Host Rock

Selection of the potential repository emplacement area was based on several considerations, which include (1) depth below the ground surface sufficient to protect *nuclear waste* from exposure to the environment, (2) extent and characteristics of the host rock, (3) location away from major faults that could adversely affect the stability of underground openings or act as pathways for water flow that could eventually lead to radionuclide release, and (4) location of the water table in relation to the proposed repository (DIRS 104956-CRWMS M&O 1993, pp. 5-99 to 5-101).

DOE selected the middle to lower portion of the Topopah Spring Tuff as the potential repository horizon. The rock is strongly welded with variable *fracture* density and void space; experience gained from the

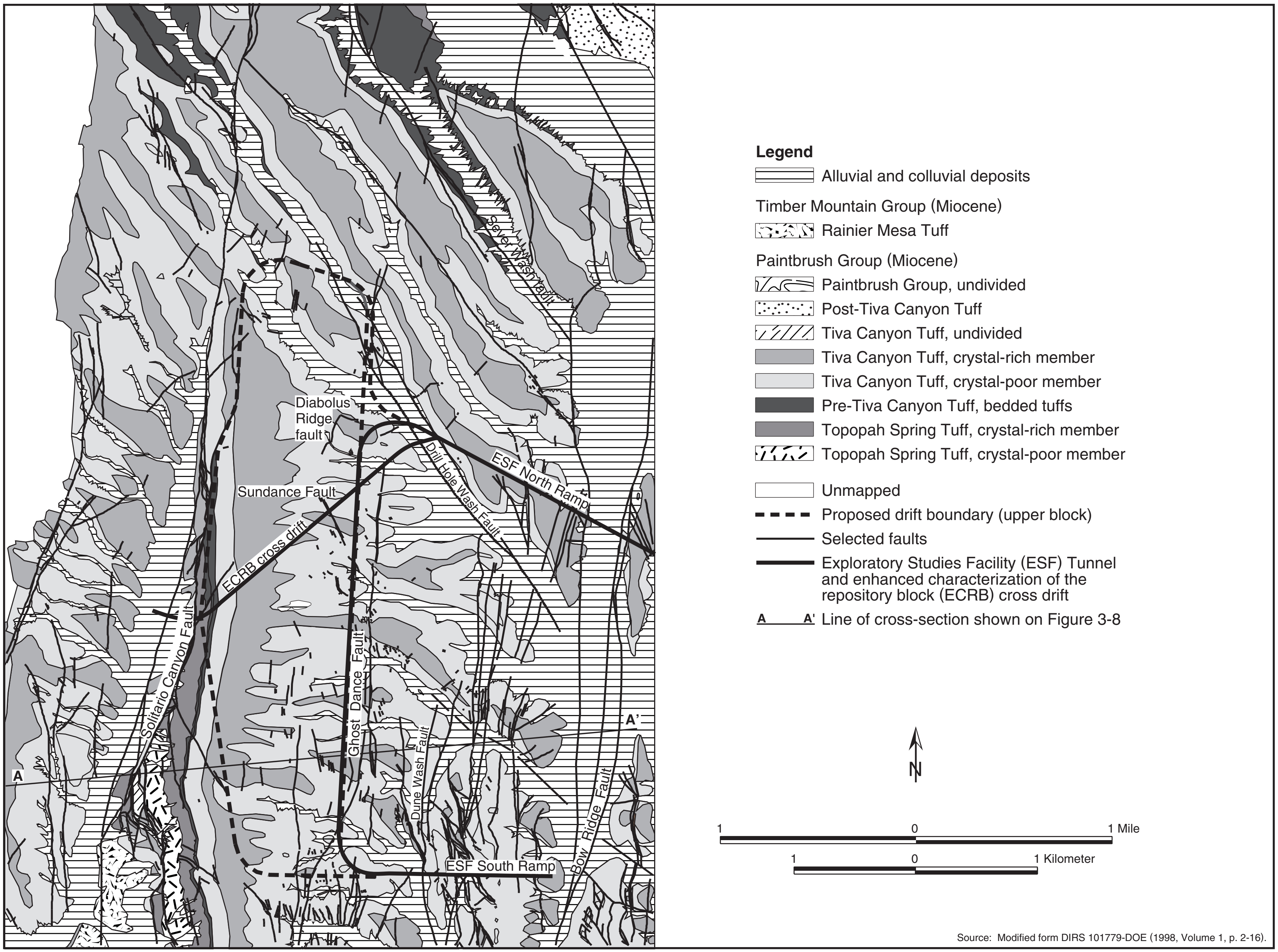
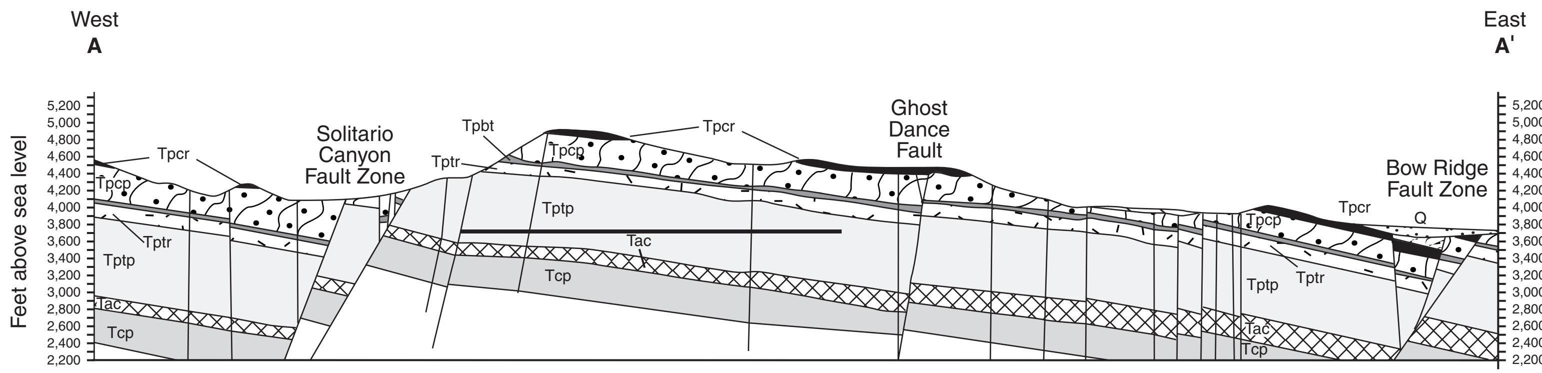


Figure 3-7. General bedrock geology of the proposed repository Central Block Area.



Legend

Q - Alluvial and colluvial deposit

Timber Mountain Group

Tmr - Rainier Mesa Tuff

Paintbrush Group

Tpcr - Tiva Canyon Tuff, crystal-rich member

Tpcp- Tiva Canyon Tuff, crystal-poor member

Tpbt - Pre-Tiva Canyon Tuff, bedded tuffs

Tptr - Topopah Spring Tuff, crystal-rich member

Tptp - Topopah Spring Tuff, crystal-poor member

Tac - Calico Hills Formation

Crater Flat Group

Tcp - Prow Pass Formation

Approximate location of proposed repository

0 1 Kilometer

0 2,000 Feet

Note: Line of cross-section indicated on Figure 3-7. Faults consistent with Figure 3-10.

Source: Modified from DIRS 101779-DOE (1998, Volume 1, p. 2-17) and DIRS 153849-DOE (2001, Figure 4-9, p. 4-38).

Figure 3-8. Simplified geologic cross-section of Yucca Mountain, west to east.

excavation of the Exploratory Studies Facility shows the capability to construct stable openings in this rock. Thermal and mechanical properties of this section of rock should enable it to accommodate the range of temperatures anticipated (thermal properties will not be affected greatly by construction and operation, as compared to postemplacement), and the identified repository volume is between major faults. Finally, the selected repository horizon is well above the present groundwater table. Based on geologic evidence the water table under Yucca Mountain has not been more than about 120 meters (390 feet) higher than its present level in the past several hundred thousand years; at such levels the water table would still be about 40 to 280 meters (130 to 920 feet) below the selected repository horizon (DIRS 151945-CRWMS M&O 2000, p. 9.4-1). Section 3.1.4 discusses the water table level further.

Potential for Volcanism at the Yucca Mountain Site

DOE has performed extensive investigations to determine the ages and nature of the volcanic episodes that produced the rocks described above (DIRS 151945-CRWMS M&O 2000, Chapters 4, 5, and 12). The rocks that form the southwestern Nevada volcanic field, characterized by large-volume silicic ash flows (including the host rock for the proposed repository), were erupted during a period of intense tectonic activity associated with active geologic faulting (DIRS 100075-Sawyer et al. 1994, all). The volcanism that produced these ash flows is complete (has not occurred in the region for more than 7.5 million years) and, based on the geology of similar volcanic systems in the Great Basin, no additional large-volume silicic activity is likely (DIRS 101779-DOE 1998, Volume 1, p. 2-85).

Basaltic volcanism in the Yucca Mountain region began about 11 million years ago as silicic eruptions waned and continued as recently as about 80,000 years ago. Basaltic volcanic events were much smaller in magnitude and less explosive than the events that produced the ash flows mentioned above. Typical products are the small volcanoes or cinder cones and associated lava flows in Crater Flat (about 1 million years old) and the Lathrop Wells volcano (possibly as young as 80,000 years) (DIRS 151945-CRWMS M&O 2000, p. 4.2-19). The potential for future volcanic activity in the Yucca Mountain region would be associated with basaltic volcanism rather than silicic activity.

Differing views on the likelihood of volcanism near Yucca Mountain result from uncertainties in the hazard assessment. To address these uncertainties, DOE has performed analyses, conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts, representing other Federal agencies (for example, the U.S. Geological Survey), national laboratories, and universities (for example, the University of Nevada and Stanford University). In 1995 and 1996, a panel of 10 scientists from these agencies and institutions and with expertise in volcanism reviewed the extensive information on volcanic activity in the Yucca Mountain vicinity and assessed the likelihood that future volcanic activity could occur at or in the vicinity of the repository (DIRS 151945-CRWMS M&O 2000, p. 12.2-21).

The probability of basaltic lava intruding into the repository is expressed as the annual probability that a volcanic event would disrupt (intersect) a repository, given that a volcanic event would occur during the period of concern. The expert panel assessed uncertainties associated with the data and models used to evaluate the potential for disruption of the potential Yucca Mountain Repository by a volcanic intrusion (dike) (DIRS 100116-CRWMS M&O 1996, all). The panel estimated the probability of a dike disrupting the repository during the first 10,000 years after closure to be 1 chance in 7,000. The estimate was recalculated to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 (with 5th and 95th percentiles of 1 chance in 130,000 and 1 chance in 2000, respectively, of a volcanic dike disrupting the repository) during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000, pp. 12.2-27 and 12.2-28 and Table 12.2-8).

3.1.3.2 Geologic Structure

Geologic structures (folds, faults, etc.) are features that result from deformation of rocks after their original formation. The present-day geologic structure of the Great Basin, including the Yucca Mountain region, is the cumulative product of multiple episodes of deformation caused by both compression and extension (stretching) of the Earth's crust.

Major east-west crustal compression occurred periodically in the Great Basin between about 350 million and 65 million years ago (DIRS 151945-CRWMS M&O 2000, pp. 4.2-21 and 4.2-27). This compression moved large sheets of older rock great distances upward and eastward over younger rocks (for example, thrust faults) to produce mountains. During the last 20 million years, crustal extension has resulted in the pattern of elongated mountain ranges and intervening basins (DIRS 151945-CRWMS M&O 2000, pp. 4.2-27 and 4.2-28). Crustal extension has resulted in vertical, lateral, and oblique movements (Figure 3-9). By about 11.5 million years ago the present mountains and valleys were well developed (DIRS 104181-Scott and Bonk 1984, all; DIRS 101557-Day et al. 1998, all).

Figure 3-7 shows the bedrock geology at the Yucca Mountain site and Figure 3-8 shows geologic structure. Figure 3-10 shows the surface traces of faults and their characteristic northerly alignment.

The crustal extension during the last 20 million years fractured the crust along the generally north-trending normal faults. Some of the crustal blocks were downdropped and tilted by movement along their bounding faults (called block-bounding faults). The estimated total displacement along the major north-trending block-bounding faults during the last 12 million years ranges from less than 100 meters (330 feet) to greater than 500 meters (1,600 feet) (DIRS 151945-CRWMS M&O 2000, pp. 12.3-38 to 12.3-58).

Measurements of Quaternary (1.6 million years to present) displacement reported on these faults range from 0 to 6 meters (0 to 20 feet), with most displacement in the 1-to-2.5-meter (3.3-to-8.2-foot) range (DIRS 101929-Simonds et al. 1995, Table 2). Displacements along faults are characterized in terms of the amount of movement per seismic event. For the set of faults of primary significance to the Yucca Mountain site, these values range from 0 to 1.7 meters (0 to 5.6 feet) per event (Table 3-8).

Table 3-8 lists the characteristics of the faults that are important to an understanding of seismic hazards to the potential repository. The Solitario Canyon fault along the west side of Yucca Mountain and the Bow Ridge Fault along the east side are the major block-bounding faults that bracket the area under consideration for the proposed repository. The proposed repository has been configured so that there would be no block-bounding faults in the emplacement zone.

Between the major north-trending, block-bounding faults there are *intrablock* or *subsidiary faults*. One intrablock fault, called the Ghost Dance fault, is in the area of the proposed repository. The Ghost Dance fault has a near-vertical dip from the surface to the depth of the repository (DIRS 151945-CRWMS M&O 2000, p. 4.6-22). This fault crosses the Exploratory Studies Facility tunnel. There is no evidence of Quaternary movement along the Ghost Dance fault (Table 3-8). Within the repository block, there are many subsidiary northwest-trending faults with smaller displacements than the block-bounding faults (DIRS 104181-Scott and Bonk 1984, all). There is no clear evidence that displacements have occurred along these subsidiary faults during the last 1.6 million years (DIRS 101929-Simonds et al. 1995, all). One short northwest-trending subsidiary fault, called the Sundance fault, transects the potential repository area (Figure 3-10).

The faults described above are associated with well-defined fractures in the rock structure. In addition to these fault fractures where there is a displacement of the sides in relation to each other, there are also fractures along which no appreciable movement has occurred. These are called *joints*. In the Paintbrush

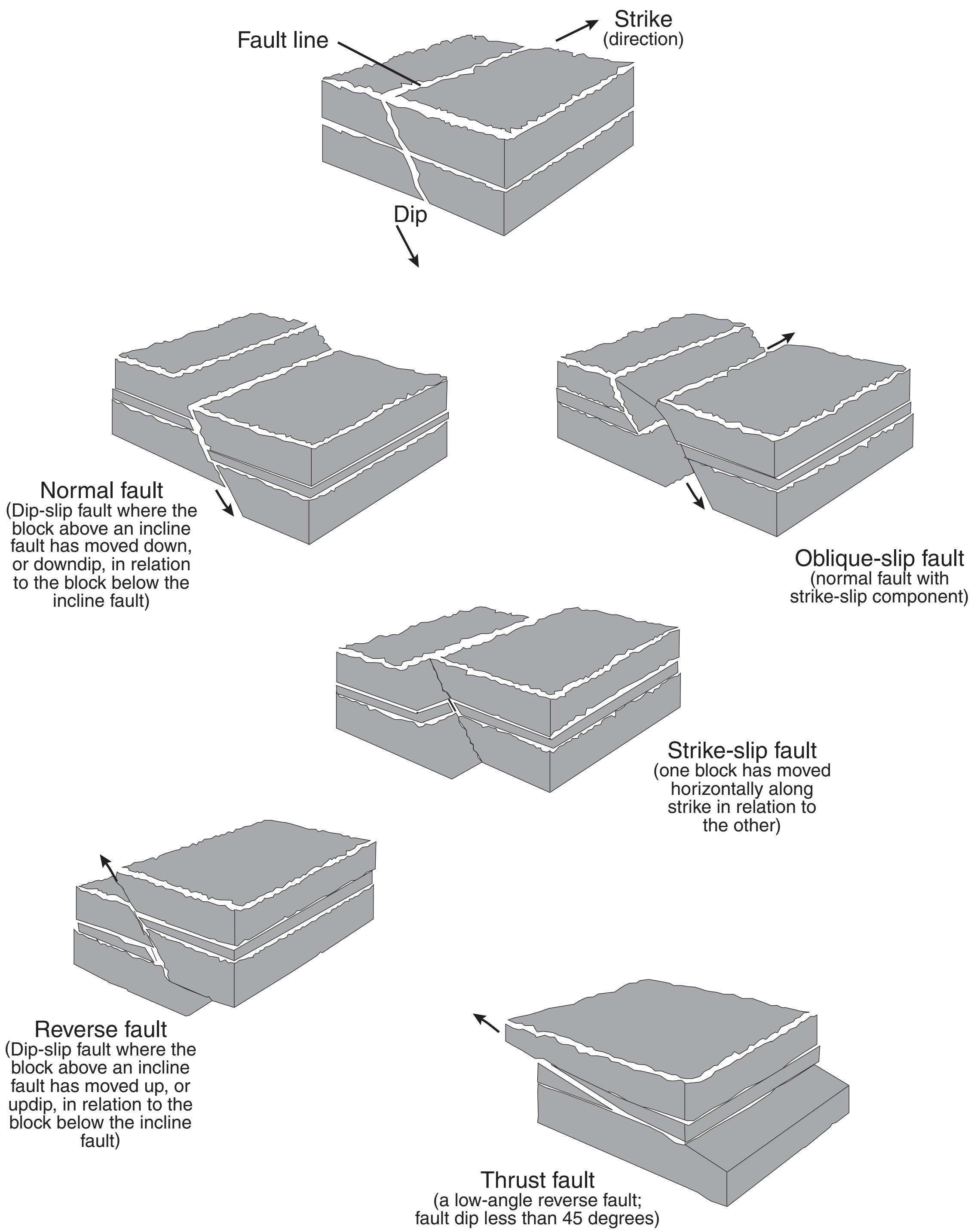


Figure 3-9. Types of geologic faults.

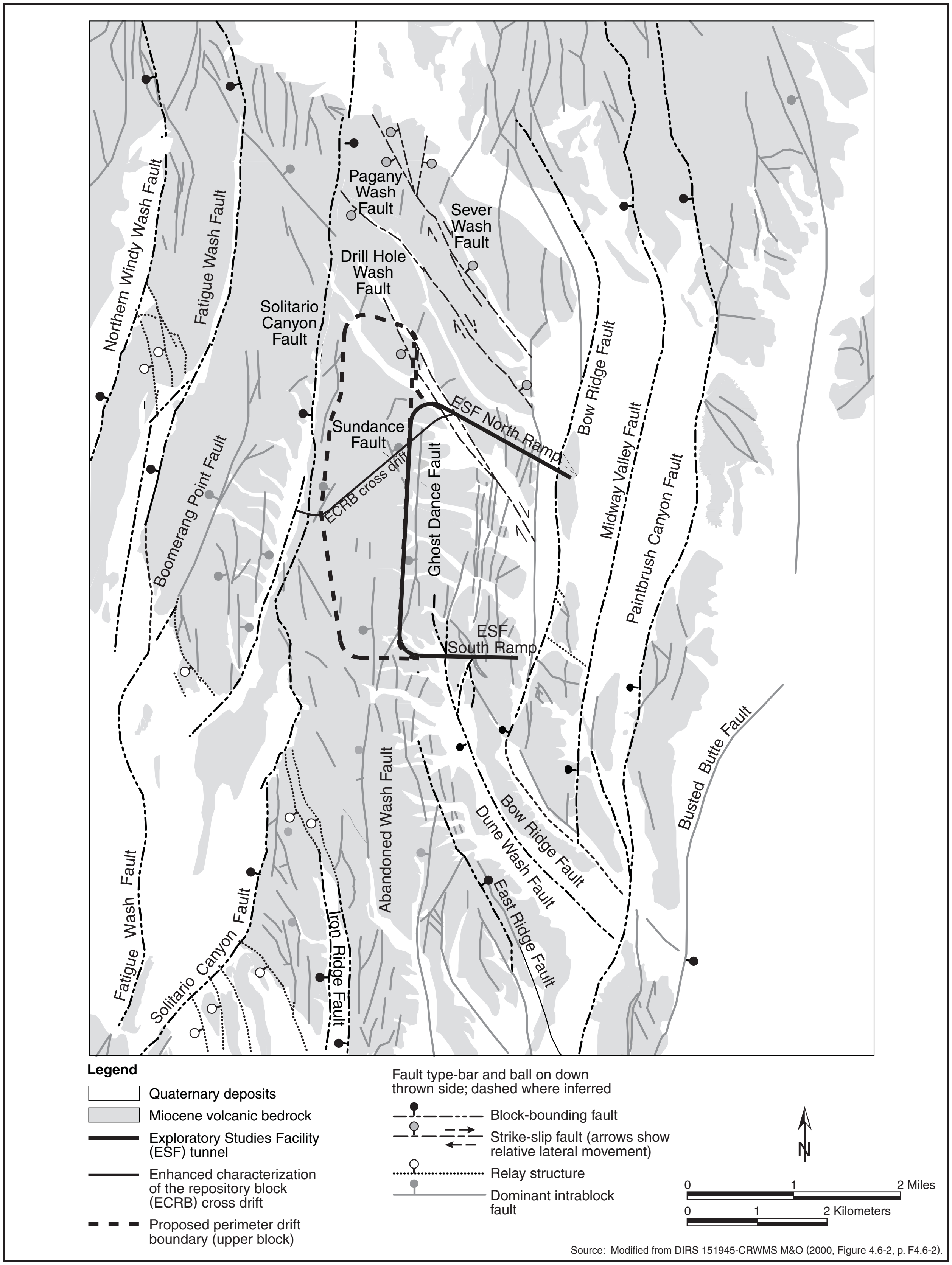


Figure 3-10. Mapped faults at Yucca Mountain and in the Yucca Mountain vicinity.

Table 3-8. Characteristics of major faults at Yucca Mountain.[a]

Fault	Surface features	Evidence of Quaternary displacement	Displacement per event[b] (meters)[c]	Total displacement; type of movement	Fault length (kilometers)[b] and dip
Crater Flat fault zone (north and south fault zones)	North zone has 2 faults 300-600 meters apart, bedrock faults and scarps, subtle scarps and lineaments in alluvium, bedrock/alluvium fault contacts.	3 of 3 trenches show multiple events; lineaments in alluvium, subtle scarps and fractures in alluvium.	0 - 0.5, north, 0.1-0.2, south	Total displacement unknown; oblique, left-lateral, west side down.	1 - 20 individual, 5 - 40 combined 70° west (north); 82° to 89° west (south)
Windy Wash fault[e]	Fault-line scarps in alluvium; bedrock/alluvium fault contacts; merges with Fatigue Wash fault.	3 of 3 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium	0.7	Less than 500 meters; mostly dip-slip, west side down	3 - 35; 77° west to vertical
Fatigue Wash fault[e]	Bedrock and alluvial scarps; fault-line scarps, lineaments in alluvium; merges with Windy Wash fault.	2 of 2 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0.3 - 1.3	75 meters; oblique left-lateral, west side down.	10 - 17; 73° west
Solitario Canyon fault[e]	Prominent fault-line scarp; discontinuous fault traces; subtle scarps in alluvium; southeastern splay is the Iron Ridge Fault.	6 of 11 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0 - 1.3	Increases southward from 0 to >500 meters; mostly normal with minor oblique left-lateral, down on east at north end, down on west at south end.	12.5 - 22; 72° west
Stagecoach Road fault	Prominent scarp and traceable faults in alluvium, merges with Solitario Canyon fault and (or) Paintbrush Canyon fault.	2 of 3 trenches show multiple events; fractures and scarps in alluvium; basalt ash in faulted alluvium.	0.4 - 0.7	400 to 600 meters; normal dip-slip to left oblique, west side down.	4 - 5 73° west
Ghost Dance fault zone[f]	Bedrock fault in zone of subparallel minor faults and breccia zones.	None	None	Increases southward from up to 5 meters at north end and 12-15 meters in central portion; dip-slip, west side down.	3 - 9; > 65° west
Bow Ridge fault[e]	Fault-line scarp along bedrock/alluvium contact; subtle lineaments; may merge along strike with Paintbrush Canyon fault.	3 of 7 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0.1 - 0.4	125 meters; oblique left-lateral, west side down.	6-10; 65° to 85° west
Midway Valley fault[e]	None, fault located on basis of geophysical evidence.	None	None in late Quaternary	40 - 60 meters; dip-slip, west side down.	1 - 5; west[g]
Paintbrush Canyon fault[e]	Bedrock and alluvial faults, scarps, and lineaments; possibly merges along strike with Stagecoach Road fault.	6 of 14 sites (10 trenches in Midway Valley and 4 exposures at Busted Butte) show multiple ruptures; basalt ash in fault plane; fractures in alluvium.	0.06 - 1.7	250 - 500 meters; dip-slip and oblique left-lateral, west side down.	10 - 26; 70° west
Northwest-trending faults[h] (not major faults)	Bedrock faults with local fault line scarps; most located by drilling and geophysical surveys.	None, with the exception of one trench across Pagany Wash fault showing absence of Quaternary displacement.	None (see column to left).	Undetermined; right-lateral to oblique right-lateral. (Except Dune Wash: 50-100 meters; normal, west side down.)	Undetermined; dip varies

a. Source: Modified from DIRS 106342-Menges and Whitney (1996, Table 4.2.1) with data from DIRS 151945-CRWMS M&O (2000, pp. 12.3-38 to 12.3-58; Tables 12.3-8a, -8b, and -9; pp. T12.3-7 to T12.3-19).
b. Preferred estimate of surface displacement associated with a prehistoric earthquake.
c. To convert meters to feet, multiply by 3.2808.
d. To convert kilometers to miles, multiply by 0.62137.
e. Block bounding fault.
f. Intrabock fault.
g. The dip and direction of this fault are uncertain.
h. Subsidiary northwest tending faults, includes the Pagany Wash, Sever Wash, Drill Hole Wash, and Dune Wash faults.

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Group (Tiva Canyon, Yucca Mountain, Pah Canyon, and Topopah Spring tuffs), joints are subdivided into three groups based on their generating mechanism and time of occurrence: early cooling joints, later tectonic joints, and joints due to erosional unloading (DIRS 151945-CRWMS M&O 2000, pp. 4.7-5 to 4.7-7). Each type of joint exhibits different characteristics with respect to its length, orientation, and connectivity. The cooling and tectonic joints have similar orientations (generally running north-south), but cooling joints include irregularly spaced horizontal joints as well. Joints due to erosional unloading are variably oriented but tend predominantly east to west, cross-wise to the cooling and tectonic joints. Tectonic joints occur throughout the Paintbrush Group and cooling joints are identified in each of the welded units. In general, the highest joint frequencies and connectivities occur in the units of the Tiva Canyon and Topopah Spring tuffs and the lowest occur in the nonwelded Yucca Mountain and Pah Canyon tuffs. Most joints, particularly cooling joints, are confined to specific rock units and do not cross unit boundaries. They do not generally form through-going features like faults. Geologic, geoengineering, and hydrologic aspects of fractures are discussed in detail in the Yucca Mountain Site Description (DIRS 151945-CRWMS M&O 2000, pp. 4.6-17 to 4.6-19, 4.7-5 to 4.7-7, 4.7-36 to 4.7-40, and 8.9-1 to 8.9-15).

DOE identified and described alternative tectonic models to explain the current geologic structure resulting from past tectonic processes and deformation events that have affected the Yucca Mountain site. These models are described in the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Section 4.3), and were considered by the experts in the Probabilistic Seismic Hazard Analysis (DIRS 100354-USGS 1998, all) discussed below. Computer models provide a means of integrating data on volcanism, deposition, and fault movement, and include a representation of the existing geologic structures and the processes that operate at depth. Tectonic models provide a basis for evaluating the processes and events that could occur in the future and potentially affect the performance of a repository. The DOE hazard assessments used models that are supported by data.

3.1.3.3 Modern Seismic Activity

DOE has monitored seismic activity at the Nevada Test Site since 1978. The epicenters of many earthquakes that the Southern Great Basin Seismic Network has located within 20 kilometers (12 miles) of Yucca Mountain do not correlate with mapped surface traces of Quaternary faults (DIRS 151945-CRWMS M&O 2000, pp. 12.3-17 and 12.3-18). This lack of correlation is a common feature of earthquakes, particularly those of smaller magnitude, in the Great Basin and elsewhere. Earthquakes in the Yucca Mountain region have focal depths (the point of origin of an earthquake below the ground surface) ranging from near-surface to about 5 to 12 kilometers (3 to 7 miles) (DIRS 151945-CRWMS M&O 2000, p. 12.3-18). The earthquake focal mechanisms are *strike-slip* to normal *oblique-slip* along moderately to steeply dipping fault surfaces. These focal mechanisms indicate the nature of the fault planes on which the earthquakes occur, as shown in Figure 3-9.

The largest recorded historic earthquake within 50 kilometers (30 miles) of Yucca Mountain was the Little Skull Mountain earthquake in 1992 (DIRS 151945-CRWMS M&O 2000, p. 12.3-7 and Figure 12.3-4, p. F12.3-4), which had a Richter magnitude of 5.6 (DIRS 151945-CRWMS M&O 2000, p. 12.3-18). This seismic event occurred about 20 kilometers (12 miles) southeast of Yucca Mountain, about a day after the magnitude 7.3 earthquake at Landers, California, 300 kilometers (190 miles) south-southeast of Yucca Mountain. The Little Skull Mountain event caused no damage at Yucca Mountain, although some damage occurred at the Field Office Center in Jackass Flats (DIRS 151945-CRWMS M&O 2000, p. 12.3-18) about 5 kilometers (3 miles) north of the epicenter.

Seismic Hazard

DOE based the design ground motion and fault displacement that could be associated with future earthquakes at Yucca Mountain on the record of historic earthquakes in the Great Basin, evaluation of prehistoric earthquakes based on investigations (trenching and detailed mapping) of the faults at Yucca Mountain, and observation of ground motions associated with modern earthquakes using the Southern Great Basin Seismic Network.

Experts have evaluated site data and other relevant information (including differing models) to assess where and how often future earthquakes will occur, how large they will be, how much offset will occur at the Earth's surface, and how ground motion will diminish as a function of distance. Two panels of scientific experts conducted the Probabilistic Seismic Hazard Analysis (DIRS 100354-USGS 1998, all); one panel characterized sources of future earthquakes and their potential for surface fault displacement and the second addressed ground motion for the Yucca Mountain region. The results of this analysis are hazard curves that show the ground motions and potential fault displacements plotted with annual frequency of being exceeded. These are used to determine the design-basis ground motions and to assess the postclosure performance of the site (DIRS 151945-CRWMS M&O 2000, pp. 12.4-3 to 12.4-7). Figure H-1 in Appendix H shows the summary hazard curve for horizontal peak ground acceleration generated from the analysis.

The expert assessments indicate that geologic fault displacement hazard is generally low. For locations not on a major block-bounding fault, displacements greater than 0.1 centimeter (0.04 inch) will be exceeded an average of less than once in 100,000 years, whereas the mean displacements that are likely to be exceeded on the block-bounding Bow Ridge and Solitario Canyon faults are 7.8 and 32 centimeters (3.1 and 13 inches), respectively (DIRS 151945-CRWMS M&O 2000, p. 12.3-86). Mitigating potential fault displacement effects would involve avoiding faults in laying out repository facilities (DIRS 151945-CRWMS M&O 2000, p. 12.3-92).

Ground motion studies have investigated the level of shaking produced at Yucca Mountain by both local and regional earthquakes, and have estimated expected ground motion from hypothetical earthquakes. These predictions of probable ground motion amplitudes and frequencies support preliminary design requirements (the Exploratory Studies Facility), and future studies will provide additional site-specific information on soil and rock properties that will enable refinement of preliminary results and facilitate design analyses to mitigate seismic risk to a potential repository (DIRS 101779-DOE 1998, Volume 1, pp. 2-86 and 2-87).

The seismic design basis for the repository specifies that structures, systems, and components important to safety should be able to withstand the horizontal motion from an earthquake with a return frequency of once in 10,000 years (annual probability of occurrence of 0.0001) (DIRS 103237-CRWMS M&O 1998, p. VII-3). A recent comprehensive evaluation of the seismic hazards associated with the site of the proposed repository (DIRS 100354-USGS 1998, Figure 7-4) concluded that a 0.0001-per-year earthquake would produce peak horizontal accelerations at a reference rock site at Yucca Mountain of about 0.53*g* (mean value). DOE needs to complete additional investigations of ground motion site effects before it can produce the final seismic design basis for the surface facilities.

A recent study published in *Science* magazine (DIRS 103485-Wernicke et al. 1998, all) claims that the crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. If higher strain rates are present, the potential volcanic and seismic hazards would be underestimated on the basis of the long-term geologic record.

As part of the Yucca Mountain site characterization activities, DOE established a 14-station, 50-kilometer (30-mile), geodetic array, centered on Yucca Mountain, and conducted surveys in 1983, 1984, and 1993. As interpreted by U.S. Geological Survey researchers (DIRS 103457-Savage et al. 1994, all), the surveys indicated no large strain accumulation and thus do not support the claims in DIRS 103485-Wernicke et al. (1998, all). The Yucca Mountain array was resurveyed by the U.S. Geological Survey in 1998

(DIRS 118952-Savage, Svarc, and Prescott 1999, all). After correction for deformation associated with the Little Skull Mountain earthquake, the data continue to indicate a strain rate about an order of magnitude lower than that reported by DIRS 103485-Wernicke et al. (1998, all).

DOE is continuing to fund additional investigations on the crustal strain rate in the Yucca Mountain region through a grant to the University of Nevada. Dr. Wernicke of the California Institute of Technology (Cal Tech) continues to monitor conditions as a principal investigator under a subcontract, and a group at the University of Nevada at Reno is tasked with providing an independent evaluation of the assumptions and processing that support the Cal Tech results. This study involves 32 geodetic monument sites with continuous Global Positioning System measurements, a significant improvement over the study reported in *Science* in 1998. The first report (DIRS 156302-Marks 2001, all) from this effort was issued during 2001 and provided a status based on data collected through May 2001. According to the report, preliminary findings from this ongoing study are that strain is accumulating in the Yucca Mountain region, but at a notably lower rate than previously reported by DIRS 103485-Wernicke et al. (1998, all). Improved results are expected over the next year of the study, including a better characterization and explanation for the strain accumulation. DOE believes the results of this study will confirm the lower crustal strain rates as reported by the U.S. Geological Survey. However, if higher crustal strain rates are shown to exist, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

3.1.3.4 Mineral and Energy Resources

The southern Great Basin contains valuable or potentially valuable mineral and energy resources, including deposits with past or current production of gold, silver, mercury, base metals, and uranium. The proximity of known deposits and the identification of similar geologic features at Yucca Mountain have led some investigators to propose that the analyzed Yucca Mountain land withdrawal area (see Figure 3-2) could have the potential for mineral resources (DIRS 103483-Weiss, Noble, and Larson 1996, p. 5-26).

DOE site investigations included evaluation of the potential for mineral and energy resources in the analyzed withdrawal area because the presence of such resources could lead to exploration and inadvertent *human intrusion* (see Chapter 5). The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Section 4.9) describes results of investigations that address relevant natural resources. Site characterization investigators identified no economic deposits of base or precious metals, industrial rocks or minerals, and energy resources, based on present use, extraction technology, and economic value of the resources (DIRS 151945-CRWMS M&O 2000, p. 4.9-12 to 4.9-14). DOE believes the potential for economically useful mineral or energy resources in the analyzed Yucca Mountain withdrawal area is low.

3.1.4 HYDROLOGY

This section describes the current hydrologic conditions in the Yucca Mountain region in terms of surface-water and groundwater system characteristics. The region of influence considered for surface water includes construction or land disturbance areas that could be susceptible to erosion, areas affected by permanent changes in surface-water flow, and areas downstream of the proposed repository that could be affected by eroded soil or potential spills of contaminants. The groundwater region of influence includes aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction and operations, and aquifers downgradient of the proposed repository that repository use, including long-term releases, could affect. Section 3.1.4.1 describes surface-water conditions, and Section 3.1.4.2 describes groundwater conditions.

The hydrologic system in the Yucca Mountain region is characterized and influenced by a very dry climate, limited surface water [annual average precipitation of about 10 to 25 centimeters (4 to 10 inches) (Section 3.1.2.2), potential evaporation of almost 170 centimeters (66 inches) per year (DIRS 101779-DOE 1998, Volume 1, p. 2-29)], and deep aquifers. Important characteristics of the hydrologic system include drainages and streambeds, streams, springs, and playa lakes. In addition, water quantity and quality are important characteristics. Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin of the larger Death Valley Regional Groundwater Flow System. Death Valley is a terminal hydrologic basin; surface water and groundwater cannot leave except by *evapotranspiration* (DIRS 100465-Luckey et al. 1996, p. 30). Important characteristics of the groundwater system include *recharge* zones (areas where water infiltrates from the surface and reaches the saturated zone), discharge points (locations where groundwater reaches the surface), unsaturated zones (the portion of the groundwater system above the water table), saturated zones (the portion of the groundwater system below the water table), and aquifers (water-bearing layers of rock that provide water in usable quantities). In combination, these characteristics define the quantity and quality of the available groundwater. This section also describes groundwater use as part of the system.

EVAPOTRANSPIRATION

Evapotranspiration is the loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants.

3.1.4.1 Surface Water

3.1.4.1.1 *Regional Surface Drainage*

Yucca Mountain is in the southern Great Basin, which generally lacks perennial streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas (Figure 3-11). Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry along most of their lengths most of the time. Exceptions include short stretches where groundwater discharges to or converges with the channel (DIRS 151945-CRWMS M&O 2000, p. 7.1-3); examples are near Beatty, Nevada; south of Tecopa, California; and in southern Death Valley, California. The river drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa (DIRS 103090-Bostic et al. 1997, pp. 103 and 112), and its course extends roughly 100 kilometers (60 miles) farther before it ends in the Badwater Basin in Death Valley (DIRS 151945-CRWMS M&O 2000, p. 7.1-2 and Figures 7.1-1 and 7.1-4, pp. F7.1-1 and F7.1-4), which is more than 80 meters (260 feet) below sea level (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). The nearest surface-water impoundments are Peterson Reservoir, Crystal Reservoir, Lower Crystal Marsh, and Horseshoe Reservoir.

The largest of these is Crystal Reservoir, a manmade impoundment at Ash Meadows, which captures the discharge from several springs in the area and has a capacity of 1.8 million cubic meters (1,500 acre-feet). Crystal Reservoir and other smaller pools in Ash Meadows drain to the Amargosa River through Carson Slough (DIRS 151945-CRWMS M&O 2000, p. 7.1-2).

3.1.4.1.2 *Yucca Mountain Surface Drainage*

Occurrence. No perennial streams, natural bodies of water (DIRS 151945-CRWMS M&O 2000, pp. 7.1-2 and 7.1-3), or naturally occurring wetlands (DIRS 104592-CRWMS M&O 1999, p. 2-14) occur at Yucca Mountain or in the analyzed land withdrawal area. Fortymile Wash, a major wash that flows to the Amargosa River, drains the eastern side of Yucca Mountain (Figure 3-12) (DIRS 151945-CRWMS M&O 2000, p. 7.1-2). The primary washes draining to Fortymile Wash at Yucca Mountain include Yucca Wash to the north; Drill Hole Wash, which, together with its tributary, Midway Valley Wash, drains most of the repository site; and Busted Butte (Dune) Wash to the south. The western side of Yucca Mountain

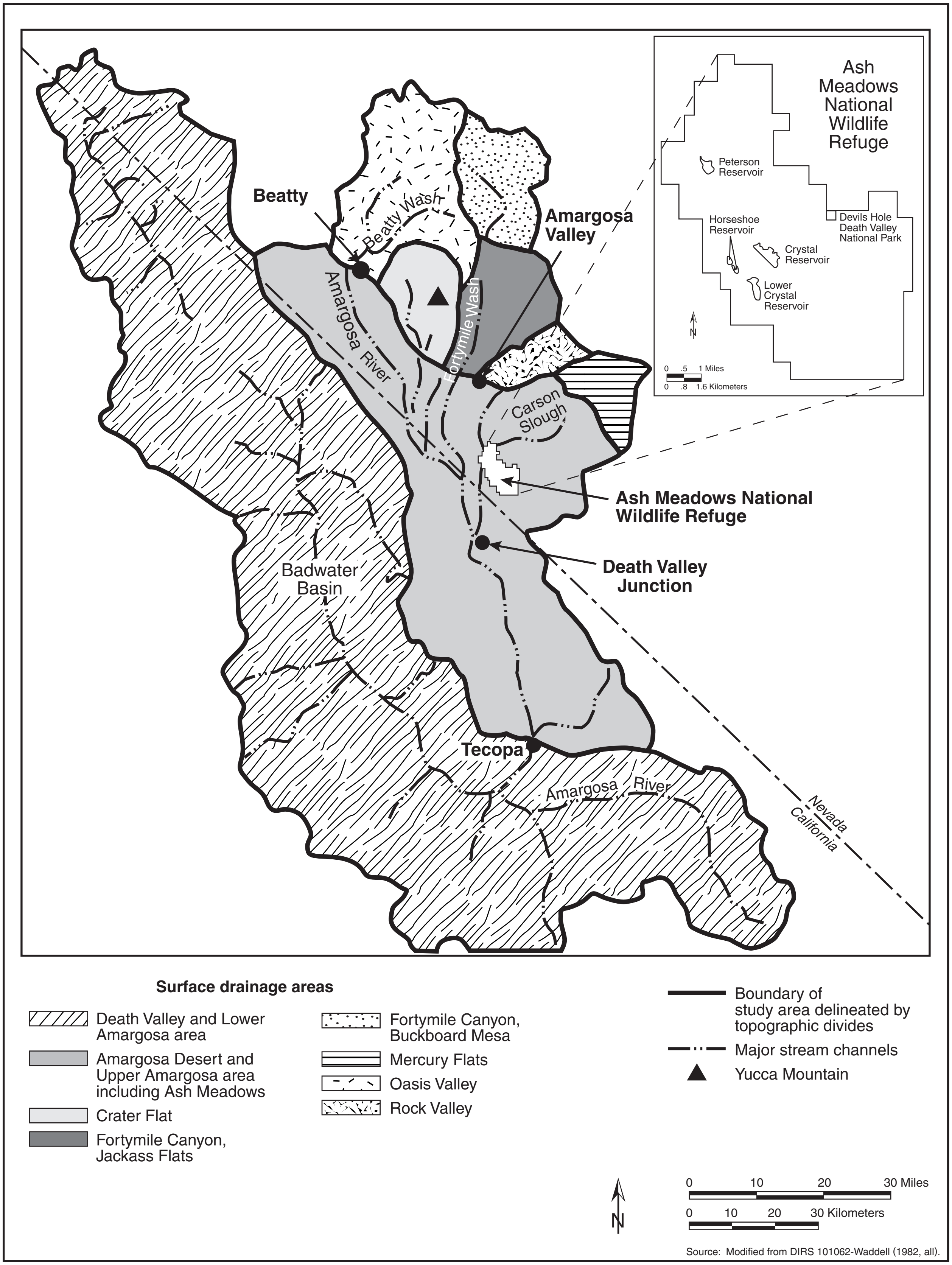

Figure 3-11. Surface areas drained by the Amargosa River and its tributaries.

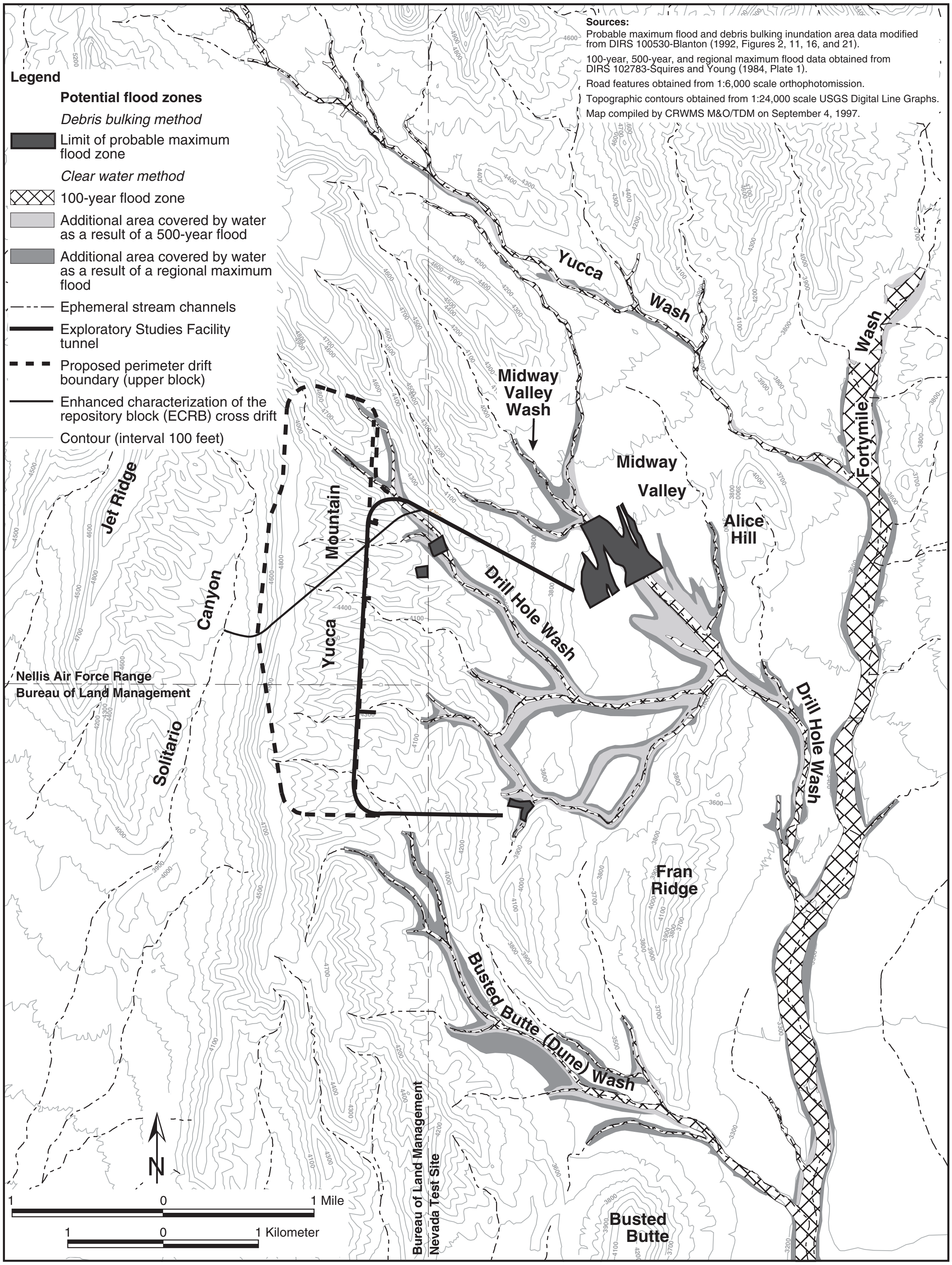

Figure 3-12. Site topography and potential flood areas.

is drained through Solitario Canyon Wash and Crater Flat, both of which eventually drain to the Amargosa River (DIRS 151945-CRWMS M&O 2000, p. 7.1-2). In this area, most of the water from summer storms is lost relatively quickly to evapotranspiration unless a storm is intense enough to produce runoff or subsequent storms occur before the water is lost (DIRS 151945-CRWMS M&O 2000, p. 7.5-1). Evapotranspiration is lower during the winter, when water from precipitation or melting snow has a better chance to result in stream flow.

Thunderstorms in the area can be local and intense, creating runoff in one wash while an adjacent wash receives little or no rain (DIRS 151945-CRWMS M&O 2000, p. 7.1-3). In rare cases, however, storm and runoff conditions can be extensive enough to result in flow being present throughout the drainage system. DIRS 155679-Glancy and Beck (1998, all) documented conditions during March 1995 and February 1998 where Fortymile Wash and the Amargosa River flow simultaneously through their primary channels to Death Valley. The 1995 event represented the first documented case of this flow condition. The 1995 event involved the higher recorded flows. The peak flow near the location where the existing Yucca Mountain access road crosses Fortymile Wash was reported as about 100 cubic meters (3,500 cubic feet) per second (DIRS 155679-Glancy and Beck 1998, p. 7). This flow is much less than that calculated as the *100-year flood* event for Fortymile Wash (as discussed in the next paragraph). The occurrence of flow throughout the drainage, however, might be a more unusual event because it would require the generation of runoff over a much larger area than the Fortymile Wash drainage, and in the same timeframe.

Flood Potential. Although flow in most washes is rare, the area is subject to flash flooding from intense summer thunderstorms or sustained winter precipitation (DIRS 151945-CRWMS M&O 2000, p. 7.3-1). When it occurs, intense flooding can include mud and debris flows in addition to water runoff (DIRS 100530-Blanton 1992, p. 2). Table 3-9 lists peak discharges for estimated floods along the main washes at Yucca Mountain, a value for a regional maximum flood. In addition to the flood estimates listed in the table, DOE used another estimating method, the *probable maximum flood* methodology [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (DIRS 103071-ANS 1992, all)] to generate another maximum flood value for washes adjacent to the existing facilities and operations at the North and South Portals (DIRS 100530-Blanton 1992, all; DIRS 108883-Bullard 1992, all). The flood value this method generates, which includes a bulking factor to account for mud and debris (including boulder-size materials), is the most severe reasonably possible for the location under evaluation and is larger than the regional maximum flood listed in Table 3-9 (DIRS 151945-CRWMS M&O 2000, pp. 7.3-3 and 7.3-4). DOE used the probable maximum flood values to predict the areal extent of flooding and to determine if facilities and operations are at risk of flood damage.

PREDICTED FLOODS

100-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 100 years.

500-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 500 years.

Regional maximum flood: The magnitude of a peak discharge based on data from extreme floods, in this case, occurring elsewhere in Nevada and in nearby states.

Probable maximum flood: The hypothetical peak discharge considered to be the most severe reasonably possible based on a probable maximum precipitation and other factors favorable for runoff.

Figure 3-12 shows the extent of estimated floods calculated for the proposed repository before the construction of the Exploratory Studies Facility. It shows the area that the estimated 100- and 500-year floods would inundate as well as the inundation area for the most conservative (highest) of the estimated maximum floods. As indicated on the figure, the partial or discontinuous inundation areas in Midway Valley Wash and the upper reaches of Drill Hole Wash are based on the probable maximum flood values derived in accordance with guidelines of the American National Standards Institute and American Nuclear Society; for other areas, the most extensive flood zones are based on the regional maximum flood levels listed in Table 3-9. The figure also shows that all floods along Fortymile Wash and Yucca Wash would remain within existing stream channels.

Table 3-9. Estimated peak discharges along washes at Yucca Mountain.[a]

Name	Drainage area (square kilometers)[b]	Peak discharge 100-year flood (cubic meters per second)[c]	Peak discharge 500-year flood (cubic meters per second)	Regional maximum flood (cubic meters per second)
Fortymile Wash	810	340	1,600	15,000
Busted Butte (Dune) Wash	17	40	180	1,200
Drill Hole Wash[d]	40	65	280	2,400
Yucca Wash	43	68	310	2,600

a. Source: DIRS 102783-Squires and Young (1984, p. 2).
b. To convert square kilometers to square miles, multiply by 0.3861.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. Includes Midway Valley and South Portal Washes as tributaries—North and South Portal Areas.

Along Busted Butte (Dune) and Drill Hole Washes, the *500-year flood* would exceed stream channels at several places, and the probable maximum flood would inundate broad areas in Midway Valley Wash near the North Portal. None of the identified flood estimates predicts water levels high enough to reach either the North or South Portal opening to the subsurface facilities (DIRS 100530-Blanton 1992, pp. 4 and 7), which would be at either end of the Exploratory Studies Facility tunnel shown in the figure.

The U.S. Geological Survey (DIRS 103469-Thomas, Hjalmarson, and Waltemeyer 1997, all) recently published a revised methodology for calculating peak flood discharges in the southwestern United States. A preliminary evaluation indicates that the methodology, if appropriate for use, could result in estimates for 100-year floods that are larger than those listed in Table 3-8 and shown in Figure 3-12. However, the new methodology affects only the 100-year flood estimate, so discharge numbers and expanded inundation lines resulting from its use would be within the bounds set by the 500-year flood.

DOE has prepared a *floodplain* assessment for the Proposed Action in accordance with the requirements of 10 CFR Part 1022. Appendix L contains the floodplain assessment.

Surface-Water Quality. Samples of stream waters in the Yucca Mountain region have been collected and analyzed for their general chemical characteristics. Because surface-water flows are rare and in immediate response to storms, data from sampling events are sparse. Results of the surface-water sample analyses (Table 3-10) bear some resemblance to those from groundwater samples, as discussed in Section 3.1.4.2.2, because both contain bicarbonate as a principal component. However, in general, the groundwaters have a higher mineral content, suggesting more interaction between rock and water (see Section 3.1.4.2.2, Tables 3-13 and 3-17).

3.1.4.2 Groundwater

This section discusses groundwater, first on a regional basis and then in the Yucca Mountain vicinity. Many studies have been conducted on the groundwater system under and surrounding Yucca Mountain. These studies provide a firm basis of understanding of the hydrology of the region. However, because

Table 3-10. Chemistry of surface water in the Yucca Mountain region.[a]

Chemical[b]	Range of chemical composition
pH	7.8 - 8.4
Total dissolved solids (milligrams per liter)	45.0 - 123
Calcium (milligrams per liter)	6.7 - 28.0
Magnesium (milligrams per liter)	0.7 - 3.9
Potassium (milligrams per liter)	3.2 - 11.0
Sodium (milligrams per liter)	2.4 - 16.0
Bicarbonate (milligrams per liter)	32.0 - 109
Chloride (milligrams per liter)	1.3 - 10.0
Sulfate (milligrams per liter)	4.1 - 24.0
Silica (milligrams per liter)	4.5 - 36.0

a. Source: DIRS 151945-CRWMS M&O (2000, Table 5.3-3, p. T5.3-7).
b. Based on 18 samples from 15 different surface-water locations (12 involve a single sampling event and 3 involve two sampling events) collected from 1984 to 1995. One milligram per liter is equivalent to one part per million.

groundwater systems are complex and difficult to study, there are differences of opinion among experts related to interpreting available data and describing certain aspects of the Yucca Mountain groundwater system. Therefore, this section also discusses the various views on the groundwater system under Yucca Mountain, where viewpoints differ.

3.1.4.2.1 *Regional Groundwater*

The groundwater flow system of the Death Valley region is very complex, involving many *aquifers* and confining units. Over distance, these layers vary in their characteristics or even their presence (DIRS 151945-CRWMS M&O 2000, pp. 9.2-5 to 9.2-10). In some areas confining units allow considerable movement between aquifers; in other areas confining units are sufficiently impermeable to support artesian conditions (where water in a lower aquifer is under pressure in relation to an overlying confining unit; when intersected by a well, the water will rise up the borehole).

In general, the principal water-bearing units of the Death Valley regional groundwater flow system (or simply Death Valley region) are grouped in three types of saturated hydrogeologic units: basin-fill alluvium (or alluvial aquifer), volcanic aquifers, and carbonate aquifers (DIRS 151945-CRWMS M&O 2000, pp. 9.2-23 and 9.2-24). An alluvial aquifer is in a *permeable* body of sand, silt, gravel, or other detrital material deposited primarily by running water. Volcanic and carbonate aquifers are in permeable units of *igneous* (of volcanic origin) and carbonate (limestone or dolomite) rock, respectively. The mountainous area that makes up the north-central portion of the Death Valley region that includes the Yucca Mountain area is often underlain by volcanic rocks and associated volcanic aquifers. The valley or basin areas to the south and southeast of Yucca Mountain contain alluvial aquifers, including those beneath the Amargosa Desert. Carbonate aquifers are regionally extensive and generally occur at large depths below volcanic aquifers or alluvial aquifers (DIRS 151945-CRWMS M&O 2000, p. 9.6-2). The discussion of groundwater at Yucca Mountain describes the position of the various aquifers and confining units in relation to each other and to stratigraphic units.

The alluvial aquifers below the Amargosa Desert receive underflow (groundwater movement from one area to another) from groundwater basins to the north as well as from basin areas to the east and, therefore, contain a mixture of water from several different aquifers (DIRS 151945-CRWMS M&O 2000, pp. 9.2-16 to 9.2-18). For example, the volcanic aquifers beneath Yucca Mountain are believed to provide inflow to the alluvial aquifers beneath the Amargosa Desert. In addition, the springs in the Ash Meadows area are fed in part by the carbonate aquifers (DIRS 101167-Winograd and Thordarson 1975, p. C53) and what is not discharged through the springs flows into groundwater moving through the alluvial aquifers at the southeast end of the Amargosa Desert and then discharges at Alkali Flat (Franklin Lake Playa) or continues as groundwater into Death Valley (DIRS 151945-CRWMS M&O 2000, pp. 9.2-17 and 9.2-18). There is also evidence that indicates a carbonate aquifer might be present below the volcanic sequence, extending from eastern Yucca Mountain south into the Amargosa Desert (DIRS 100465-Luckey et al. 1996, pp. 32 and 40).

HYDROGEOLOGIC TERMS

Permeability: Describes the ease or difficulty with which water passes through a given material. Permeable materials allow fluids to pass through readily, while less permeable materials inhibit the flow of fluids.

Aquifer: A permeable water-bearing unit of rock or sediment that yields water in a usable quantity to a well or spring.

Saturated zone: The area below the water table where all spaces (fractures and rock pores) are completely filled with water.

Confining unit (or aquitard): A rock or sediment unit of relatively low permeability that retards the movement of water in or out of adjacent aquifers.

Inflow: Sources of water flow into a groundwater system such as surface infiltration (recharge) or contributions from other aquifers.

Basins. The Death Valley regional groundwater flow system (Figure 3-13) or region covers about 50,000 square kilometers (19,000 square miles) (DIRS 151945-CRWMS M&O 2000, p. 9.2-3). Straddling the Nevada-California border, this flow system includes several prominent valleys (Amargosa Desert, Pahrump Valley, and Death Valley) and their separating mountain ranges and extends north to the Kawich Valley, encompassing all of the Nevada Test Site (DIRS 151945-CRWMS M&O 2000, Figures 9.2-1 and 9.2-2, pp. F9.2-1 and F9.2-2). The major recharge areas are mountains in the east and north portions of the region (DIRS 151945-CRWMS M&O 2000, pp. 9.2-11 and 9.2-15). The discharge points are primarily to the south and include the southernmost discharge points in Death Valley and intermediate points such as Ash Meadows in the Amargosa Desert and Alkali Flat (DIRS 151945-CRWMS M&O 2000, p. 9.2-13). Therefore, flow is primarily to the west or south. Figure 3-13 shows a slightly reduced outline for the regional flow system that some Yucca Mountain Site Characterization Project modeling efforts (for example, DIRS 100131-D'Agnese et al. 1997, all) have used as the boundary. This reduced area is divided into the Northern, Central, and Southern Death Valley subregions. The Central Death Valley subregion contains the area of Yucca Mountain.

Hydrologic investigations of the Death Valley region date back to the early 1900s, with early work performed primarily by the U.S. Geological Survey (DIRS 100131-D'Agnese et al. 1997, p. 4). More recently, studies by both the U.S. Geological Survey and the State of Nevada have included efforts to collect and compile water-level data from regional wells (DIRS 151945-CRWMS M&O 2000, p. 9.2-39). DOE has collected groundwater-level data from wells at Yucca Mountain and in neighboring areas on a routine basis since 1983, and has used the levels to which water rises in these wells—called the *potentiometric surface*—to map the slope of the groundwater surface and to determine the direction of flow. Figure 3-14 is a potentiometric surface map of the Death Valley regional groundwater flow system. Based on these and other data, groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley (Figure 3-15). The area around Yucca Mountain is in the central subregion of the Death Valley region, and this subregion has three groundwater basins: (1) Ash Meadows, (2) Alkali Flat-Furnace Creek, and (3) Pahute Mesa-Oasis Valley (DIRS 102893-Rush 1971, pp. 10 and 11; DIRS 101062-Waddell 1982, pp. 13 to 20; DIRS 100465-Luckey et al. 1996, pp. 28-30; and DIRS 100131-D'Agnese et al. 1997, p. 65). The aquifers below Yucca Mountain have been included in the Alkali Flat-Furnace Creek groundwater basin because of evidence that the groundwater discharges mainly at Alkali Flat (Franklin Lake Playa) and potentially to the Furnace Creek Wash area of Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18).

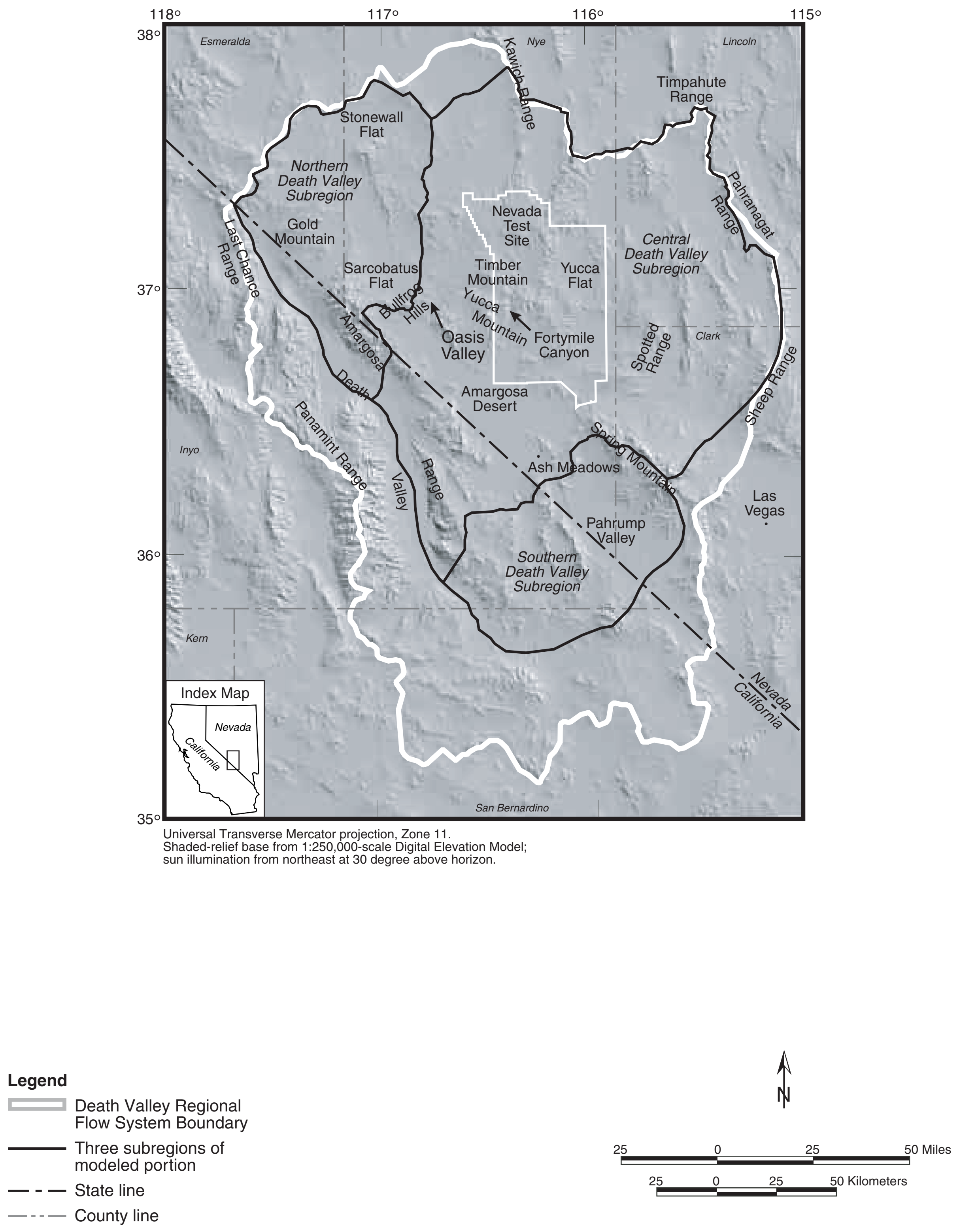

Figure 3-13. Boundaries of Death Valley regional groundwater flow system.

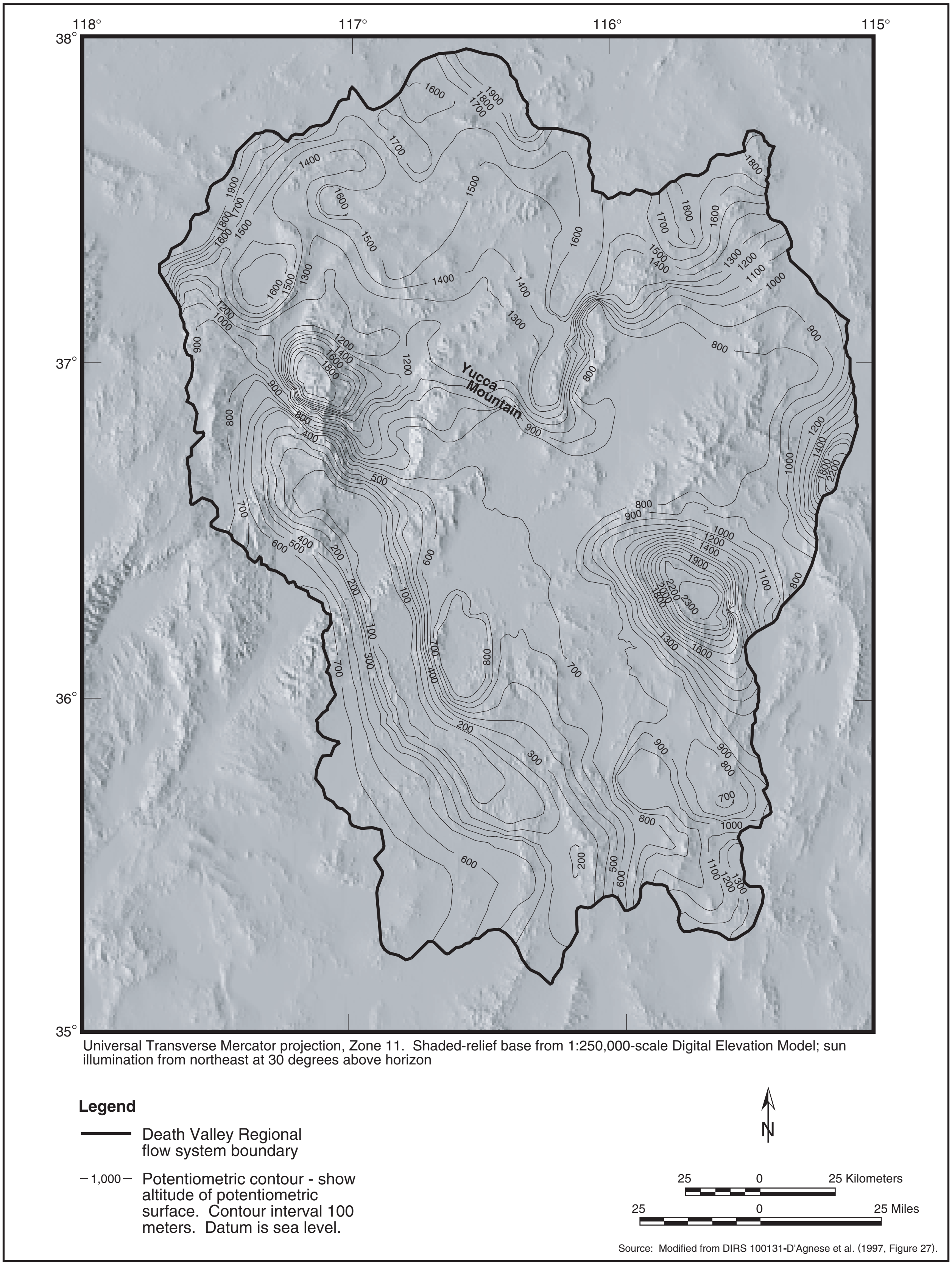

Figure 3-14. Estimated potentiometric surface of the Death Valley region.

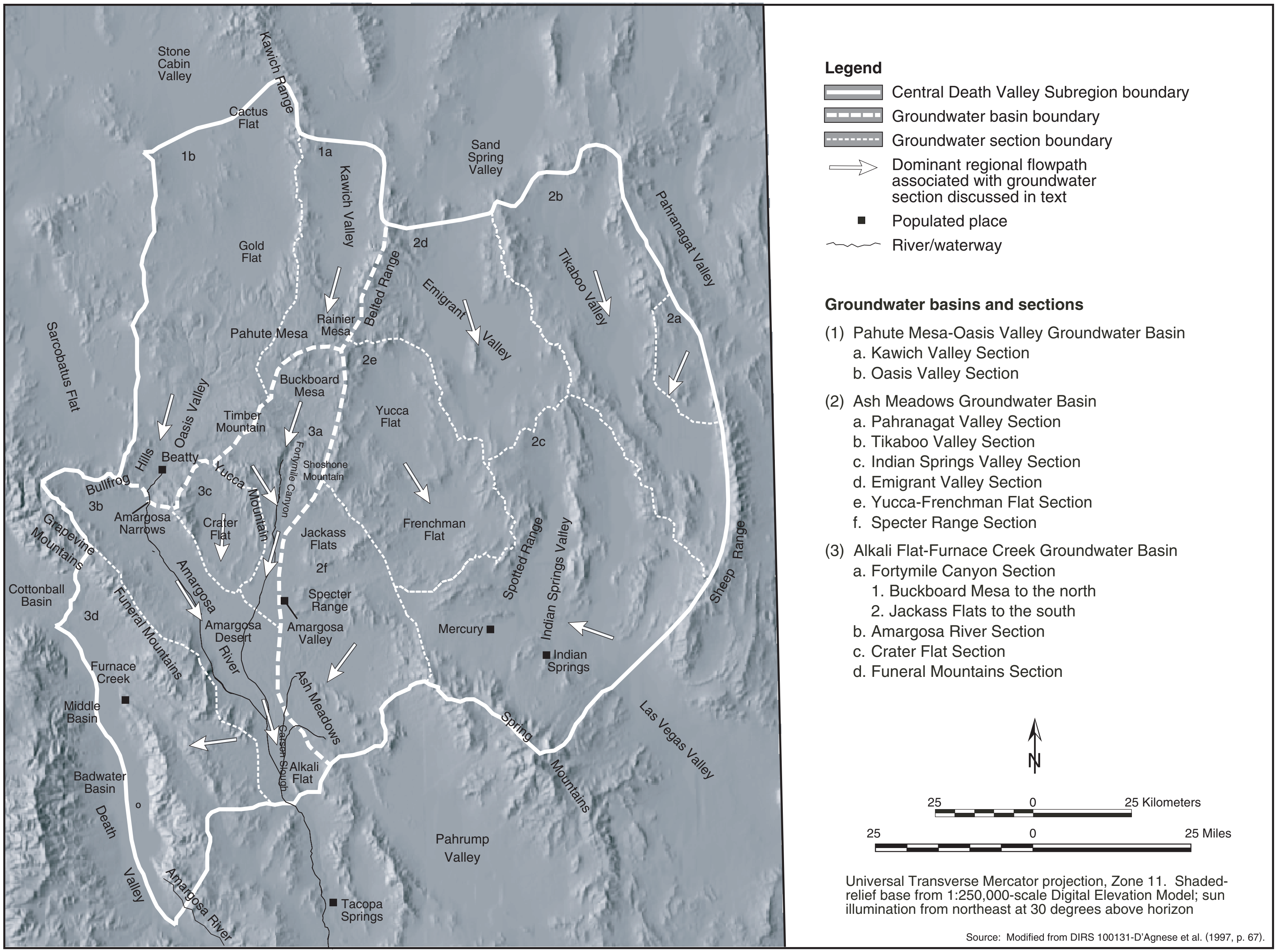

Figure 3-15. Groundwater basins and sections of the Central Death Valley subregion.

The Ash Meadows groundwater basin is the easternmost of the three basins that make up the Central Death Valley subregion. It underlies eastern portions of the Nevada Test Site (Yucca Flat, Frenchman Flat, Mercury Valley, Rock Valley), parts of Shoshone Mountain, Rainier Mesa to the north, and the Ash Meadows area of the Amargosa Desert in the south. Inflow is principally from the Spring Mountains, Pahranagat Range, Sheep Range, and Pahranagat Valley in the eastern portion of the basin (DIRS 100131-D'Agnese et al. 1997, pp. 67 and 68). Outflow is basically in the form of discharge to the surface and underflow to the lower portion of the Alkali Flat-Furnace Creek groundwater basin. The primary discharge point for this groundwater basin is Ash Meadows, where springs occur in a line along a major fault (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). Estimates of discharge at Ash Meadows range from 21 million to 37 million cubic meters (17,000 to 30,000 acre-feet) per year (DIRS 103022-Walker and Eakin 1963, p. 24; DIRS 100131-D'Agnese et al. 1997, p. 46).

The Pahute Mesa-Oasis Valley groundwater basin includes Oasis Valley, Gold Flat, the southern parts of Cactus Flat and Kawich Valley, and the western portion of Pahute Mesa. Recharge areas are primarily in the north in the Belted and Kawich Ranges and Pahute Mesa, but include Timber Mountain and the Bullfrog Hills, and along the Amargosa River and its tributaries (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). Subsurface outflow is into the Amargosa Desert of the Alkali Flat-Furnace Creek groundwater basin, and has been estimated at about 0.49 million cubic meters (400 acre-feet) per year (DIRS 106695-Malmberg and Eakin 1962, p. 26).

The Alkali Flat-Furnace Creek groundwater basin is bordered on the northwest by the Pahute Mesa-Oasis Valley basin and on the east by the Ash Meadows basin. This groundwater basin includes portions of the Nevada Test Site (parts of Rainier Mesa, Pahute Mesa, and Buckboard Mesa to the north, Shoshone Mountain, Yucca Mountain, and Jackass Flats in the southern half), Crater Flat in the west, and part of Death Valley and the central part of the Amargosa Desert in the south (DIRS 100131-D'Agnese et al. 1997, pp. 67 to 69). As shown in Figure 3-15, this basin includes the groundwater area designated as the Fortymile Canyon Section, which includes the area of Buckboard Mesa to the north and a portion of Jackass Flats to the south. Groundwater moving beneath the proposed repository site is in the Fortymile Canyon section.

In the immediate vicinity of Yucca Mountain, sources of recharge to the groundwater include Fortymile Wash and precipitation that infiltrates the surface. However, these local sources are not among the primary sources of recharge in the area that makes up the Alkali Flat-Furnace Creek groundwater basin. The primary sources of surface recharge in this area are infiltration on Pahute Mesa, Rainier Mesa, Timber Mountain, and Shoshone Mountain to the north (DIRS 151945-CRWMS M&O 2000, p. 9.2-18), and the Grapevine and Funeral Mountains to the south (DIRS 100131-D'Agnese et al. 1997, p. 68). One numerical model of infiltration for Yucca Mountain used energy- and water-balance calculations to obtain an average infiltration rate of 4.7 millimeters (0.2 inch) a year over the potential repository area for the current climate (DIRS 151945-CRWMS M&O 2000, Table 8.2-9, p. T8.2-7). This represents less than 3 percent of an average annual precipitation rate of about 200 millimeters (8 inches) used in the model for the crest at Yucca Mountain. In comparison, areas such as Pahute Mesa, Timber Mountain, and Shoshone Mountain receive more precipitation (DIRS 103021-DOE 1997, Plate 1) and have higher estimated percentages of precipitation infiltrating deep into the ground and eventually becoming recharge to the aquifer.

Water infiltrating at Yucca Mountain and becoming recharge to the groundwater would join with water in the Fortymile Canyon Section (Figure 3-15). From there the general direction of groundwater flow is to the Amargosa Desert basin and then Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18). There have been many estimates of the amount of groundwater moving along this path. One study (DIRS 103016-State of Nevada 1971, p. 50) that is still used extensively by the State of Nevada in its groundwater planning efforts estimated annual groundwater movement of 10 million cubic meters (8,100 acre-feet) from the area of Jackass Flats to the Amargosa Desert and 23.4 million cubic meters

(19,000 acre-feet) from the Amargosa Desert to Death Valley. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres) (the largest repository footprint under any of the operating modes), assuming 4.7 millimeters (0.2 inch) of infiltration per year, would be about 0.2 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

DOE has performed a study (DIRS 157072-BSC 2001, all) to develop an "expected-case" model of groundwater flow in the saturated zone from beneath Yucca Mountain. The primary objective of the study was to evaluate the effects of several specific elements of conservatism in the groundwater flow model used in the Total System Performance Assessment (TSPA; see Chapter 5 and Appendix I). The study looked at the physical parameter values used in that model, for example the diffusion coefficient, porosity for fractured tuffs, and *permeability* for alluvial materials. It also looked at the location assumed in the TSPA where the groundwater flow path in the saturated zone changes from tuff to alluvial material. The recent effort looked at data collected on several specific parameters that would support what were felt to be more realistic, less conservative values. The expected-case model was run with these parameters changed and assuming a nonsorbing tracer was released as a point source to the water table beneath the proposed repository. The results of these model runs indicated it would take in the range of 1,000 to 1,500 years for 50 percent of the tracer to reach a distance of 20 kilometers (12 miles) in the groundwater flow path (DIRS 157072-BSC 2001, Figure 10, p. 43). Some of the tracer would find its way to faster pathways; some would take longer to travel the distance. DOE believes these estimates of groundwater travel time in the saturated zone represent reasonable estimates of what occurs in the natural setting.

As water in the Alkali Flat-Furnace Creek groundwater basin moves south through the Amargosa Desert, eastern portions of the flow are joined by underflow from the Ash Meadows groundwater basin (DIRS 101779-DOE 1998, Volume 1, pp. 2-56 to 2-58). The line of springs formed by discharge from the Ash Meadows groundwater basin provides much of the boundary between the two basins (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). In this area there is a marked decline of about 64 meters (210 feet) in water table elevation between Devils Hole and Carson Slough, approximately 6.4 kilometers (4 miles) to the west (DIRS 103415-Dudley and Larson 1976, p. 23). This elevation decline indicates that the potential groundwater flow is from Ash Meadows toward the Alkali Flat-Furnace Creek groundwater basin, rather than the opposite. The primary groundwater discharge point for this groundwater basin is Alkali Flat (Franklin Lake Playa) as indicated by the potentiometric surface (or slope) of the groundwater and hydrochemical data. A small portion could move toward discharge points in the Furnace Creek area of Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18).

Different researchers have speculated that the general flow boundaries of the three groundwater basins in the Central Death Valley subregion are in slightly different locations (DIRS 100131-D'Agnese et al. 1997, p. 59). Some studies [for example, DIRS 101062-Waddell (1982, p. 15)] have placed the Kawich Valley area in the Alkali Flat-Furnace Creek groundwater basin rather than in the Pahute Mesa-Oasis Valley groundwater basin as shown in Figure 3-15. This uncertainty in general flow boundaries is a reflection of the complex groundwater flow systems in the Death Valley region. The differing interpretations of the groundwater basin boundaries do not, however, disagree on the relative location of the aquifers below Yucca Mountain, which are consistently placed in the central Alkali Flat-Furnace Creek basin.

To reduce uncertainties, studies of the regional groundwater flow system are continuing. This is particularly true of that portion of the flow system that is downgradient of Yucca Mountain. Nye County, under a Cooperative Agreement with DOE, has implemented the Early Warning Drilling Program to install a series of wells in the Amargosa Valley area and the southern part of the Nevada Test Site. The purpose of this program is to characterize and monitor the saturated zone along possible transport pathways from Yucca Mountain. At the time this document was prepared, plans were underway to extend this program, which was originally set at 3 years (with a scheduled end date of November 2001). Under terms of the agreement, Nye County has had the responsibility to drill, test, and monitor a series of shallow and deep wells to investigate the upper volcanic or alluvial aquifers and the deep carbonate aquifer. The objective of the work is to determine aquifer characteristics, water chemistries, and flow paths. The County provides DOE splits of all samples collected and copies of all data obtained. DOE will continue to study the saturated zone south of Yucca Mountain through the simultaneous collection of data from this program and the use of data obtained by Nye County. In addition, a set of wells will be installed in Fortymile Wash to help identify the extent of the alluvium and valley fill along the potential flow path. Some of these wells will also be used to support an Alluvial Testing Complex, where aquifer and tracer tests in the alluvium and valley fill will be conducted. DIRS 156115-NWRPO (2001, all) described its efforts for Fiscal Years 1996 to 2001 in an August 2001 report prepared for DOE. Some of the groundwater findings discussed in this report include the following:

- Valley-fill deposits in the Amargosa Desert Area are very complex. Subsurface investigations have shown evidence of groundwater compartments as a result of faulting in the underlying rock. The conceptual hydrogeological model being developed from this information suggests that these compartments and boundaries between compartments serve either as groundwater flow pathways or as barriers. However, with several exceptions, the number and locations of compartments have not yet been well defined.

- Water level monitoring and temperature logs in wells suggest an upward gradient from underlying carbonate basement rocks into overlying valley-fill sediments.

- Evidence of transient (that is, varying over time) flow conditions in the past 50 years suggests it might be appropriate to calibrate groundwater flow models to transient flow conditions rather than the assumed steady-state conditions.

Although the Nye County report discusses these and other findings, Nye County and DOE have shared test results and data throughout the program. DOE has used and will continue to use the data collected from the Nye County and alluvial testing programs to refine its understanding of flow and transport mechanics south of Yucca Mountain. The information gained from these and other studies will be used to evaluate the accuracy and adequacy of similar information used in assessing the long-term performance of the proposed repository. The new information will also be used, as appropriate, in future iterations of conceptual and numerical models supporting the long-term performance assessment (see Chapter 5).

Use. Table 3-11 summarizes groundwater use in the Yucca Mountain region. The *hydrographic areas* listed in the table are basically a finer division of the subregions and groundwater basins discussed above; their locations are roughly consistent with the sectional divisions shown in Figure 3-15. These locations do not precisely match the groundwater area designations described in the preceding discussion because hydrographic areas generally reflect topographic divides (such as mountain ranges and valleys) that in some cases do not correspond to divides based on groundwater movement. The hydrographic area designations are important because the State of Nevada uses them as the basic units in its water planning and appropriations efforts.

DOE has been using small amounts of Jackass Flats hydrographic area groundwater for Nevada Test Site operations, and Yucca Mountain activities have contributed to water use from this source. Most water use in the Alkali Flat-Furnace Creek groundwater basin, however, occurs south of Yucca Mountain, from the Amargosa Desert alluvial aquifer (DIRS 151945-CRWMS M&O 2000, p. 9.2-23). Between 1985 and 1992, water use in the Amargosa Desert from this aquifer averaged 8.1 million cubic meters (6,600 acre-feet) a year for agriculture, mining, livestock, and domestic purposes (DIRS 147766-Thiel 1999, p. 15).

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Table 3-11. Perennial yield and water use in the Yucca Mountain region.

Hydrographic area[a]	Perennial yield[b,c] (acre-feet per year)[d]	Current appropriations[e,c] (acre-feet per year)	Average annual withdrawals 1995-1997 (acre-feet)	Chief uses
Jackass Flats (Area 227a)	880[f] - 4,000	500[g]	340[h]	Nevada Test Site programs and site characterization of Yucca Mountain. Minor amounts of water are also discharged for tests at Yucca Mountain.
Crater Flat (Area 229)	220 - 1,000	1,200[i]	140[j]	Mining, site characterization of Yucca Mountain
Amargosa Desert (Area 230)	24,000 - 34,000	27,000	14,000[j]	Agriculture, mining, livestock, municipal, wildlife habitat
Oasis Valley (Area 228)	1,000 - 2,000	1,700	N/A[k]	Agriculture, municipal

a. A specific area in which the State of Nevada allocates and manages the groundwater resources. See Figure 3-20.
b. The quantity of groundwater that can be withdrawn annually from a groundwater reservoir, or basin, for an indefinite period of time without depleting the reservoir; also referred to as *safe yield.*
c. Sources: DIRS 147766-Thiel (1999, p. 5-12); perennial yield values only, DIRS 101811-DOE (1996, pp. 4-117 and 4-118).
d. An *acre-foot* is a commonly used hydrologic measurement of water volume equal to the amount of water that would cover an acre of ground to a depth of 1 foot. To convert acre-feet to cubic meters, multiply by 1,233.49; to convert to gallons, multiply acre-feet by 325,851.
e. The amount of water that the State of Nevada authorizes for use; the amount used might be much less. These appropriations do not cover Federal Reserve Water Rights held by the Nevada Test Site or Air Force.
f. The low estimate for perennial yield from Jackass Flats breaks the quantity down further into 300 acre-feet for the eastern third of the area and 580 acre-feet for the western two-thirds.
g. Area 227a appropriations include about 370 acre-feet for Yucca Mountain characterization activities.
h. Source of Area 227a withdrawals: DIRS 101486-Bauer et al. (1996, p. 702) and DIRS 103090-Bostic et al. (1997, p. 592) for withdrawals from wells J-12 and J-13 at the Nevada Test Site.
i. Area 229 appropriations include temporary mining rights and 61 acre-feet for Yucca Mountain characterization activities.
j. Sources of Area 229 and 230 withdrawals: DIRS 102890-La Camera, Westenburg, and Locke (1996, p. 74) and DIRS 103011-La Camera and Locke (1997, p. 77).
k. N/A = not available.

As Table 3-11 indicates, water use averaged about 17 million cubic meters (14,000 acre-feet) a year from 1995 through 1997. As listed in Table 3-11, groundwater in the Amargosa Desert is heavily appropriated—at much higher levels than is actually withdrawn.

The Ash Meadows area of the Amargosa Desert has restrictions on groundwater withdrawal as a result of a U.S. Supreme Court decision (DIRS 148102-Cappaert v. United States 1976, all) to protect the water level in Devils Hole. Devils Hole became a National Monument in 1952 to preserve the Devils Hole pupfish and the pool in which the fish live. The pool contains a rock shelf that is critical to the survival of the Devils Hole pupfish because it provides an area for the fish to feed and spawn. Withdrawal of water from the connected aquifer has caused the water level in the pool to decline. The Supreme Court found that an existing Federal water right precluded development of the aquifer to the extent that the water level in the pool be maintained at a level providing adequate coverage of the rock shelf and, thereby, providing the necessary habitat for the pupfish. The Ash Meadows National Wildlife Refuge (see Figure 3-11), which includes the Devils Hole area, was established in 1984 (see Section 3.1.5.1.3). As noted above in the discussions of basins and regional groundwater movement, groundwater flowing beneath Yucca Mountain does not contribute to the groundwater beneath the area of Ash Meadows. However, the slope of the water table from Ash Meadows to the Amargosa Desert could be affected by changes in the Desert's water table elevation.

Table 3-11 lists water volumes (*perennial yield*, appropriations, and withdrawals) in acre-feet. This unit of volume is common in hydrology and water resource planning. This EIS describes water volumes in both metric (cubic meters) and English (acre-feet) units.

Groundwater Quality. The U.S. Geological Survey has accumulated and evaluated almost 90 years of groundwater data for the Yucca Mountain region and, in more recent years, has periodically collected and analyzed groundwater quality samples (DIRS 104986-CRWMS M&O 1999, pp. 6 to 9). A recent sampling effort (DIRS 104828-Covay 1997, all) looked for a wide range of inorganic and organic constituents, as well as general water quality properties. This effort collected samples from five groundwater sources in the Amargosa Desert region and three from the immediate vicinity of Yucca Mountain (as discussed in Section 3.1.4.2.2). The regional sampling locations included two wells in the central Amargosa Desert, one well in the Ash Meadows area, and two springs along the border between the Alkali Flat-Furnace Creek and Ash Meadows groundwater basins. Selected results from the recent groundwater sampling effort are listed in Table 3-12.

Table 3-12. Concentrations of selected water quality parameters in the regional groundwater.[a,b,c]

Parameter	Range of reported concentrations (milligrams per liter)	Parameter	Range of reported concentrations (milligrams per liter)
Aluminum	0.0021 - 0.0049	Lead	<0.001 - 0.0013
Antimony	<0.001 (all)	Manganese	<0.001 - 0.0022
Arsenic	0.008 - 0.022	Mercury	<0.0001 (all)
Barium	0.0012 - 0.067	Molybdenum	0.0027 - 0.010
Beryllium	<0.001 (all)	Nickel	<0.001 (all)
Boron	0.114 - 1.06	Nitrite	<0.010 (all)
Cadmium	<0.001 (all)	Nitrite plus nitrate	<0.050 - 2.17
Chloride	6.6 - 100	Selenium	<0.001 - 0.019
Chromium	0.0022 - 0.0065	Silver	<0.001 (all)
Copper	<0.001 - 0.001	Strontium	0.041 - 1.53
Cyanide	<0.01 (all)	Sulfate	18 - 420
Fluoride	1.6 - 2.3	Thallium	<0.0005 (all)
Iron	<0.003 - 0.014	Total dissolved solids (TDS)	217 - 1,110
Organochlorine and organonitrogen compounds (analysis for 45 constituents)	None detected[d] (0.00001 - 0.001)	Zinc	<0.001 - 0.027
Volatile organic compounds (analysis for 60 constituents)	None detected[d] (0.001 - 0.006)	Semivolatile organic compounds (analysis for 57 constituents)	None detected[d] (0.003 - 0.040)

a. Source: DIRS 104828-Covay (1997, all).
b. Samples collected in May 1997 from eight locations (five in the Amargosa Desert region and three in the vicinity of Yucca Mountain).
c. Parameters selected for display are primarily those identified in EPA's Primary and Secondary Drinking Water Standards.
d. "None detected" indicates no results were above the analytical laboratory's detection limits. The range of reported detection limits is in parentheses.

The U.S. Geological Survey effort compared the regional groundwater quality measurements to the primary and secondary drinking water standards established by the Environmental Protection Agency [DIRS 104876-EPA 1993, all; see also the Safe Drinking Water Act, as amended, 42 U.S.C. 300(f) *et seq.*]. Though drinking water standards are for public water supply systems, it is common to compare results from groundwater sampling and analysis to these standards for an indication of groundwater quality. The findings indicated that the five groundwater sources met primary drinking water standards, but that a few sources exceeded secondary and proposed standards. Specifically, four of the wells exceeded a proposed standard for radon (Section 3.1.8.2 discusses the natural occurrence of radon in the Yucca Mountain region) and one of those four exceeded secondary standards for sulfate and total dissolved solids and a proposed standard for uranium. Overall, however, regional groundwater quality is generally good and consistent with the State of Nevada description that most groundwater aquifers in the State are suitable, or marginally suitable, for most uses (DIRS 148164-NDWP 1999, all). Additional water quality data for wells on the Nevada Test Site are available in the *Final Environmental Impact*

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Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada (DIRS 101811-DOE 1996, pp. 4-124 to 4-126). Section 3.1.4.2.2 discusses radiological parameters, including results from regional sample locations.

3.1.4.2.2 *Groundwater at Yucca Mountain*

Groundwater at Yucca Mountain occurs in an unsaturated zone and a saturated zone. This section describes these zones and the characteristics of the groundwater in them.

> **SUBSURFACE FORMATIONS CONTAINING WATER**
>
> **Unsaturated zone:** The zone of soil or rock between the land surface and the *water table*.
>
> **Saturated zone:** The region below the *water table* where rock pores and *fractures* are completely saturated with *groundwater*.
>
> **Perched water bodies:** Saturated lenses (thin layers of water) surrounded by unsaturated conditions.

Unsaturated Zone

Water Occurrence. The unsaturated zone at Yucca Mountain extends down from the crest of the mountain about 750 meters (2,500 feet) to the water table (the upper surface of the saturated zone) (DIRS 151945-CRWMS M&O 2000, p. 8.1-1). The primary emplacement area (the upper block) of the proposed repository would be in the unsaturated zone, at least 160 and up to 400 meters (530 up to 1,300 feet) above the present water table (DIRS 151945-CRWMS M&O 2000, p. 9.4-1). The excavation of the Exploratory Studies Facility, including the Enhanced Characterization of the Repository Block *Cross-Drift*, involved more than 11 kilometers (8.4 miles) of tunnels and testing alcoves. Throughout this excavation, only one fracture was observed to be moist (DIRS 154565-Levich et al. 2000, p. 404); there was no active flow of water. Boreholes in the unsaturated zone identified water in the rock matrix, along faults and other fractures, and in isolated saturated zones of *perched water* (DIRS 151945-CRWMS M&O 2000, p. 8.5-1) (Figure 3-16). The water found in the pores of the rock matrix is chemically different from water found in fractures, perched water, or water in the saturated zone (DIRS 151945-CRWMS M&O 2000, pp. 8.6-1 and 8.6-2). Perched water in Yucca Mountain occurs where fractured rock overlies rock of low permeability such as unfractured rock, and upslope from faults where permeable or fractured rock lies against less permeable rock and fault fill material. Perched water bodies occur approximately 100 to 200 meters (330 to 660 feet) below the proposed repository horizon near the base of the Topopah Spring welded tuff unit (DIRS 151945-CRWMS M&O 2000, p. 8.5-10) (Figure 3-16). Water flow along fractures probably is responsible for recharging the perched water bodies. The apparent age of the perched water based on carbon-14 dating shows residence times of 3,500 to 11,000 years (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). Although there are limitations in the use of carbon-14 dating on water (such as knowing the initial activity of carbon-14, estimating sources of losses or gains, and adjusting for postnuclear age contributions), the perched water is believed to be too recent to be an accumulation of pore water from the rock matrix. Water chemistry data (discussed below) that show the perched water with different characteristics than the pore water provide additional, possibly stronger, evidence that pore water does not contribute significantly to the perched water. To learn how recently recharge might have occurred, these dating efforts also looked for the presence of tritium, which would indicate contributions from water affected by atmospheric nuclear weapons tests (after 1952). The results indicate that if tritium has reached the perched water bodies, it is in quantities too small for reliable detection (DIRS 151945-CRWMS M&O 2000, p. 5.3-30).

Hydrologic Properties of Rock. The unsaturated zone at Yucca Mountain consists of small areas of alluvium (clay, mud, sand, silt, gravel, and other detrital matter deposited by running water) and colluvium (unconsolidated slope deposits) at the surface underlain by volcanic rocks, mainly fragmented

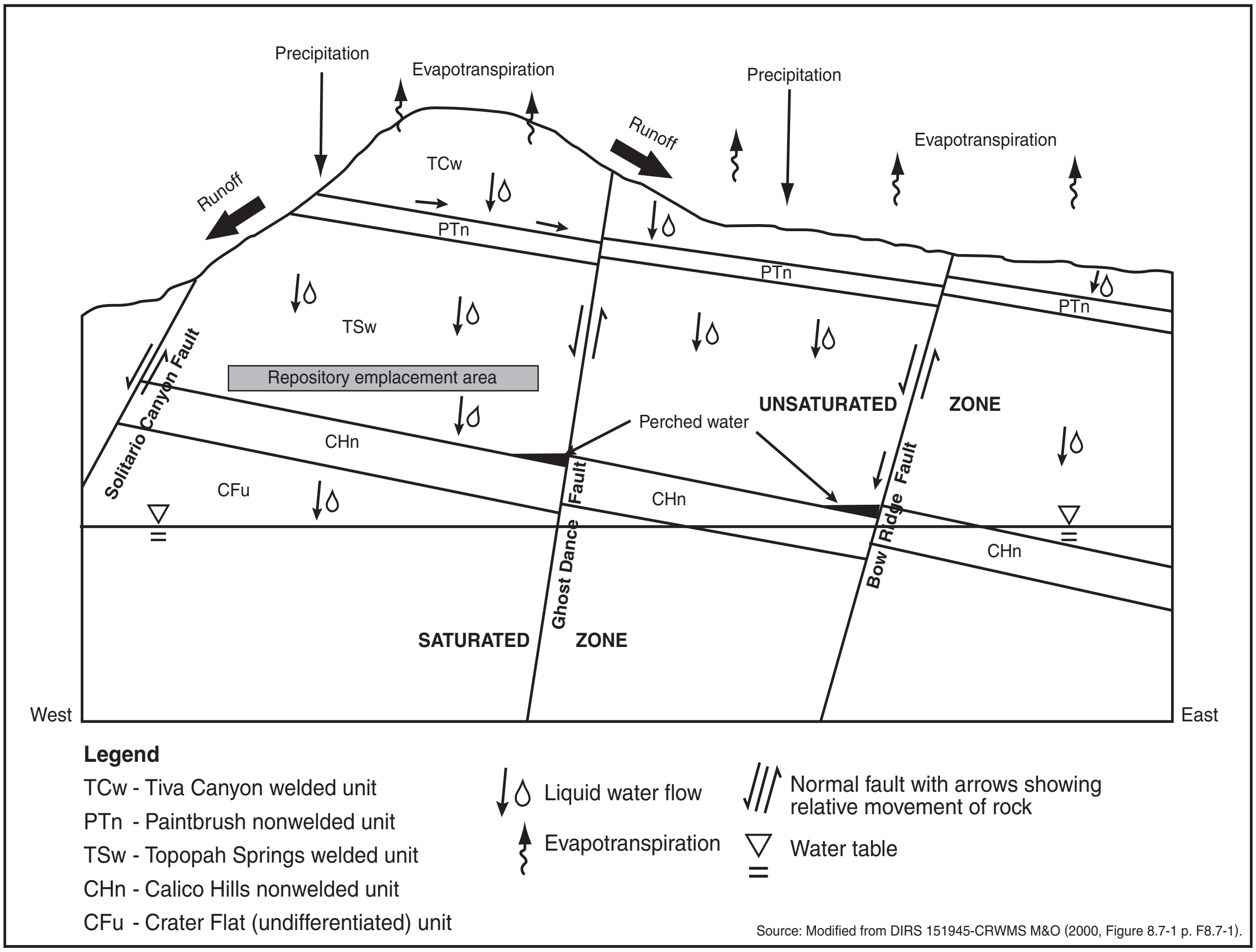

Figure 3-16. Conceptual model of water flow at Yucca Mountain.

materials called tuffs that have varying degrees of welding (DIRS 151945-CRWMS M&O 2000, p. 8.1-1). The hydrologic properties of tuffs vary widely. Some layers of tuff are welded and have low matrix porosities, but many contain fractures that allow water to flow more quickly than through the rock. Other layers, such as nonwelded and bedded tuff, have high matrix porosities but few fractures (DIRS 151945-CRWMS M&O 2000, p. 8.9-2). Some layers have many small hollow bubble-like structures (called lithophysae) that tend to reduce water flow in the unsaturated zone.

Rock units defined by a set of hydrologic properties do not necessarily correspond to rock units defined by geologic properties and characteristics. For geologic studies, rocks are generally divided on the basis of characteristics that reflect the rock origin and manner of deposition. Hydrogeologic units, on the other hand, reflect the manner in which water moves through the rock. A stratigraphic unit and a hydrogeologic unit commonly do not represent the same layer of rock. For example, a rock *stratum* classified as a single stratigraphic unit based on *lithology* or chronology, such as a tuff generated by a volcanic event, can be divided into separate hydrographic units based on hydrologic properties. Further, because the physical processes of water movement are very different under unsaturated conditions than under saturated conditions, the hydrogeologic units defined in the unsaturated zone can differ from those defined when the same rock sequence is saturated. Figure 3-17 shows the relationship between the stratigraphic units discussed in Section 3.1.3 and the hydrogeologic units discussed in this section, including the aquifers and confining units that make up the area's groundwater system. Table 3-13 lists the hydrogeologic units in the unsaturated zone at Yucca Mountain.

Era	Geologic Age	Stratigraphic unit	Approximate range of thickness (meters)	Hydrogelogic units: Unsaturated	Hydrogelogic units: Saturated	Comments
Cenozoic Era	Quaternary and Tertiary Periods	Alluvium, colluvium, eolian deposits, spring deposits, basalt lavas, lacustrine deposits, playa deposits	**0-130**	QAL, alluvium	QTa, Valley-fill aquifer; QTc, valley-fill confining unit	QAL restricted to stream channels on Yucca Mountain; QTa occurs mainly in Amargosa Desert; major water-supply source**;** subsurface extent of the QTc unit is not well established
	Tertiary Period	Timber Mountain Group Rainier Mesa Tuff				Minor erosional remnants at Yucca Mountain
		Paintbrush Group Tiva Canyon Tuff	0-150	TCw Tiva **C**anyon welded unit		Mainly densely welded; caprock on Yucca Mountain; not known in saturated zone at or near Yucca Mountain
		(bedded tuff) Yucca Mountain Tuff Pah Canyon Tuff	20-100	PTn Paintbrush nonwelded unit		Includes bedded and nonwelded tuffs between basal part of Tiva Canyon Tuff and upper part of Topopah Spring Tuff
		Topopah Spring Tuff (vitrophyre and non-welded tuffs at base)	290-360	TSw Topopah Spring welded unit	uva, Upper volcanic aquifer	About 300 meters of densely welded tuff in unsaturated zone; host rock for repository; in saturated zone where downfaulted to east, south, and west of site
		Calico Hills Formation	150-500	CHn Calico Hills nonwelded unit	uvc, Upper volcanic confining unit	Mainly nonwelded tuff, with thin rhyolite lavas in northern site area; varies from vitric in southwest site area to zeolitic where near or below water table
		Crater Flat Group Prow Pass Tuff Bullfrog Tuff Tram Tuff	200-500	CFu Crater Flat undifferentiated unit	mva Middle volcanic aquifer	Small occurrence in unsaturated zone; widespread in saturated zone; variably welded ash-flow tuffs and rhyolite lavas; commonly zeolitized; most permeable zones are fracture-controlled
		Unnamed flow breccia Lithic Ridge Tuff	400-1,000		mvc, Middle volcanic confining unit	Nonwelded tuff, pervasively zeolitized
		Volcanics of Big Dome			lva, Lower volcanic aquifer	Lava flows and welded tuff; not known at Yucca Mountain
	(Lower Tertiary?)	Older volcanics			lvc, Lower volcanic confining unit	Nonwelded tuff, pervasively zeolitized; tuffaceous sediments in lower part
Paleozoic Era	Permian/ Pennsylvanian Periods	Bird Spring Formation Tippipah Limestone	1,000 ±		uca, Upper carbonate aquifer	Limited distribution in saturated zone north and east of Yucca Mountain
	Mississippian/ Devonian Periods	Eleana Formation (Chainman Shale)	2,500 ±		ecu, Eleana confining unit	Argillite (mudstone) and siltstone; occurrence inferred beneath volcanics of northern Yucca Mountain
	Devonian Silurian Ordovician Cambrian Periods	Devils Gate Limestone, Nevada Formation, Ely Springs Dolomite, Eureka Quartzite, Pogonip Group, Nopah Formation, Dunderberg Shale, Bonanza King Formation, Upper Carrara Formation	8,500 ±		lca, Lower carbonate aquifer	Mainly limestone and dolomite with relatively thin shales and quartzites; major regional aquifer, more than 5 kilometers (3.1 miles) thick
		Lower Carrara Formation			qcu, Precambrian confining unit	Dolomite, shale
Proterozoic (Upper Precambrian)		Proterozoic rocks				Quartzite, slate, marble; fractures commonly healed by mineralization

Source: Modified from DIRS 151945-CRWMS M&O (2000, Tables T9.3-1 and T9.3-2, Thickness date: Figures 4.5-3 and 4.5-4, pp. F4.5-3 and F4.5-4, and Table 9.2-2, pp. T9.2-2 and T9.2-3).

Figure 3-17. Correlation of generalized stratigraphy with unsaturated and saturated hydrogeologic units in the Yucca Mountain vicinity.

Table 3-13. Hydrogeologic units in the unsaturated zone at Yucca Mountain.[a]

Unit and characteristics[b]	Thickness (meters)[c]
Quaternary alluvium/colluvium Unconsolidated stream deposits beneath valleys and loose slump deposits beneath slopes; porosity and permeability medium to high.	0 - 130
Tiva Canyon welded unit (TCw) Mainly pyroclastic flow tuffs; porosity typically 10 to 30 percent; saturation commonly 40 to 90 percent.	0 - 150
Paintbrush nonwelded unit (PTn) Includes the Yucca Mountain and Pah Canyon Tuffs and uppermost part of the welded Topopah Spring Tuff; porosity generally high, 30 to 50 percent; matrix saturation, 40 to 70 percent.	20 - 100
Topopah Spring welded unit (TSw) Mainly devitrified ash flow tuff; porosity generally low, less than 20 percent, but up to 40 percent in glassy zones; matrix saturation generally greater than 50 percent, commonly greater than 80 percent.	290 - 360
Calico Hills nonwelded unit (CHn) Made up of four subunits, the lower three of which contain zeolites; the unit also includes Prow Pass Tuff (pyroclastic flow) of the Crater Flat Group; porosity generally 20 to 40 percent; matrix saturation 30 to 90 percent, commonly near 100 percent in zeolitic zones.	150 - 500
Crater Flat undifferentiated unit (CFu) Consists of welded Bullfrog Tuff (stratigraphically above) and nonwelded Tram Tuff (stratigraphically below); is below water table in much of the area, but is unsaturated beneath western part of Yucca Mountain; Bullfrog Tuff has low porosity, less than 20 percent, and high matrix saturation, close to 100 percent; Tram Tuff has porosity 20 to 40 percent; and high matrix saturation.	200 - 500

a. Source: DIRS 151945-CRWMS M&O (2000; Units and Descriptions - pp. 4.5-18 to 4.5-33 and 8.3-6 to 8.3-10; Porosity and Saturation - Figures 8.3-1 and 8.3-2, pp. F8.3-1 and F8.3-2, and Table 8.3-2, p. T8.3-3; and Thickness - Figures 4.5-3 and 4.5-4, pp. F4.5-3 and F4.5-4).

b. Letters in parentheses are used in Figures 3-16 and 3-17

c. To convert meters to feet, multiply by 3.2808.

Water Source and Movement. When precipitation falls on Yucca Mountain, part leaves as runoff, part evaporates, and part infiltrates the ground. Some of the water that infiltrates the ground eventually evaporates in the arid climate or passes to plants; the remainder percolates into the ground as infiltration.

Some of the infiltration remains at shallow levels, some eventually rises to the surface as vapor, and some (called *net infiltration*) moves deeper into the unsaturated zone. The estimated net infiltration for the current climate is 3.6 millimeters (0.1 inch) per year in a study area of about 120 square kilometers (48 square miles) that includes Yucca Mountain and 4.7 millimeters (0.2 inch) per year in the potential repository area (DIRS 151945-CRWMS M&O 2000, Tables 8.2-7 and 8.2-9, pp. T8.2-6 and T8.2-7). These are estimates of average net infiltration for fairly large surface areas. Because of the arid climate, the sporadic nature of storms, and the variation in topography, the actual amount of annual infiltration varies widely from year to year and across the area. Yucca Mountain Project studies have shown that net infiltration varies over segments of the larger areas based, in part, on the amount of unconsolidated material present. The estimated net infiltration over the study area ranges from zero where alluvium is more than 6 meters (20 feet) thick to 8 centimeters (3 inches) and more where thin alluvium overlies highly permeable bedrock (DIRS 100147-Flint, Hevesi, and Flint 1996, p. 91). On a year-to-year basis, the average net infiltration over the repository might range from 0.4 to 11.6 millimeters (0.02 to 0.5 inch) (DIRS 151945-CRWMS M&O 2000, Table 8.2-9, p. T8.2-7).

Groundwater movement in the unsaturated zone at Yucca Mountain occurs in the pore space (matrix) of rock units and along faults and fractures of rock units. Water movement through the pore space of rock units is a relatively slow (or stagnant) process compared with flow through faults and fractures (DIRS 151945-CRWMS M&O 2000, p. 8.9-10). Water movement through faults and fractures is believed to be episodic in nature (occurring at discrete times related to periods of high surface infiltration), is capable of traveling rapidly through rock units, and is the likely source of perched water in the unsaturated zone (DIRS 151945-CRWMS M&O 2000, pp. 8.9-3 to 8.9-6).

The characteristics of groundwater movement through specific rock units differ based on their hydrogeologic properties (DIRS 151945-CRWMS M&O 2000, pp. 8.9-2 to 8.9-3). Water that infiltrates into the Tiva Canyon welded unit can often be transported rapidly through fractures as deep as the underlying Paintbrush nonwelded unit. Due to its high porosity and low fracture density, the Paintbrush unit tends to slow the downward velocity of water flow dramatically in relation to highly fractured units such as the Tiva Canyon unit. However, isotopic (chlorine-36) analysis has identified isolated pathways that provide relatively rapid water movement for very small amounts of water (DIRS 151945-CRWMS M&O 2000, p. 8.12-16) through the Paintbrush nonwelded unit to the top of the underlying Topopah Springs welded unit where, due to increased fracturing, it has the potential to travel quickly through the unit.

DOE has used the ratio of chlorine-36 (a naturally occurring *isotope*) to total chlorine to determine where and when moisture has moved in the unsaturated zone at Yucca Mountain. High enough chlorine-36 ratios indicate waters exposed to very small amounts of fallout associated with above-ground nuclear weapons testing (called bomb-pulse water). The methodology used in these studies is complicated and is still under investigation; however, findings thus far have been valuable in reaching certain conclusions.

CHLORINE-36 STUDIES

These studies use the fact that a very small portion of chlorine in the atmosphere consists of the radioactive isotope chlorine-36. The production of chlorine-36 (caused in part by interactions between argon molecules and high-energy protons and neutrons in the atmosphere) is sufficiently balanced with the rate of its removal as atmospheric fallout that the ratio of chlorine-36 to stable chlorine (chlorine-35 and -37) at any given location remains fairly constant in atmospheric salts deposited on land, such as that dissolved in rainwater. Once chlorine is isolated from the surface environment (as when dissolved in water percolating down through the soil and subsurface rocks), subsequent changes in the chlorine-36-to-total-chlorine ratio can be attributed to decay of the chlorine-36 (DIRS 101005-Levy et al. 1997, p. 2) (that is, if the residence times are long enough in relation to the 301,000-year half-life of this radionuclide). Measuring the chlorine-36-to-total-chlorine ratio in underground water or in residues it leaves behind, and knowing what the ratio was at the time of recharge provides a means of estimating the age of the water. In reality, slight variations over time in the atmospheric ratio and the potential for some minor production of chlorine-36 in the subsurface has made the use of this technique for water dating difficult, and its use is still under investigation. However, the atmospheric ratio of chlorine-36 to total chlorine has increased by orders of magnitude as a result of above-ground nuclear testing during the past 50 years. As a consequence, the technique has been very successful in tracing underground water or water residues that originated at the surface within the past 50 years, with the so-called *bomb-pulse signal* indicating very young water.

Chlorine-36 analyses at Yucca Mountain have identified locations where water has moved fairly rapidly (in several decades) from the surface to the depth of the proposed repository and also where it has moved very slowly (thousands to tens of thousands of years). The chlorine-36 studies included one study that collected 247 rock samples along the 8-kilometer (5-mile) Exploratory Studies Facility tunnel (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). About 70 percent of the samples were from areas thought to be more likely to show evidence of rapid water movement [that is, areas of broken rock such as faults, fractures, or breccia zones (areas where rock composed of fragments of older rocks melded together)] (DIRS 100144-Fabryka-Martin et al. 1997, p. 4-13).

Most of the samples (77 percent) had ratios that were ambiguous in that they fell within the range over which the chlorine-36-to-total-chlorine ratio has varied over the last 30,000 years or more (DIRS 100144-Fabryka-Martin et al. 1997, p. 3-1). Results of these samples indicate that the groundwater travel times from the surface to the repository depth in most areas probably are thousands to tens of thousands of years. This is because there is little evidence for measurable radioactive decay of the chlorine-36 signal in the subsurface. However, a few samples indicated ratios low enough to suggest the possible presence of zones of relatively old or stagnant water.

About 13 percent of the samples (31 samples) had high enough chlorine-36-to-total-chlorine ratios to indicate the water originated from precipitation occurring in the past 50 years (that is, nuclear age precipitation) (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). Locations where bomb-pulse water occurred were correlated with the physical conditions in the mountain and on the surface that could lead to, or otherwise affect, the findings. The conclusion to date of these ongoing studies is that relatively fast transport of water through the mountain is controlled by the following factors (DIRS 104878-CRWMS M&O 1998, p. 3-2):

- The presence of a continuous fracture path from the surface: The limiting factor is a fracture or fault cutting the Paintbrush nonwelded bedded tuffs (PTn) hydrogeologic unit (this prominent unit is above the repository horizon; see Figure 3-16 and Table 3-13). Fracture pathways are normally available in the welded portions of the overlying Tiva Canyon and underlying Topopah Spring units. This is consistent with hydrologic modeling of *percolation* through this nonwelded bedded tuff, which indicates that there must be fracture pathways due to faulting or other disturbances for water to travel through this unit in 50 years or less. Section 3.1.3 discusses fault locations inside Yucca Mountain.

- The magnitude of surface infiltration: There must be enough infiltration to sustain a small component of flow along the connected fracture pathway.

- The residence time of water in the soil cover: This time must be less than 50 years; to achieve this, the depth of the soil overlying the fracture pathway must be less than an estimated 3 meters (10 feet).

Several important factors affect a discussion of chlorine-36 studies. Ratios of naturally occurring radioactive chlorine-36 to the other isotopes of chlorine are on the order of one chlorine-36 atom to approximately two trillion (2,000,000,000,000) other chlorine atoms. Samples designated as showing evidence of elevated, "bomb-pulse" chlorine-36 still have exceedingly minute amounts of this isotope, containing only two to eight times the amount that occurs naturally. The scale of these measurements and the significance being placed on them makes understanding the sources of chlorine-36 in the underground environment and the intricacies of the analytical procedures extremely important. To ensure the correct interpretation of this subtle chemical signal (that is, of elevated amounts of chlorine-36), studies are underway to determine whether independent laboratories and related isotopic studies corroborate the findings.

Water percolating to the depth of the repository and beyond is affected not only by fractures but also by the nature of the hydrogeologic units it encounters. Pressure testing in boreholes indicates that fractures in the Topopah Spring tuff (the rock unit in which DOE would build the repository) are very permeable and extensively interconnected (DIRS 151945-CRWMS M&O 2000, p. 8.12-5). Below the repository level, low-permeability zones impede the vertical flow of water in the Calico Hills nonwelded unit (which includes the basal part of the Topopah Springs Tuff, Figure 3-17), forming perched water bodies (DIRS 151945-CRWMS M&O 2000, pp. 8.9-5 and 8.9-6). The primary source of the perched water is water traveling down along faults and fractures. In the dipping or sloped strata beneath Yucca Mountain,

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perched water bodies require vertical impediments such as fault zones where less permeable rock and fault-gouge material block the lateral flow of water (Figure 3-16). If these conditions do not exist at the fault zone, the fault can provide a downward pathway. Even in cases where fault zones are barriers to lateral water flow, they can be very permeable to gas and moisture flow along the fault plane and permit the rapid vertical flow of water from the land surface to great depth. Studies of heat flux above and below the perched water zone appear to indicate more water percolation above the perched water than below (DIRS 100627-Bodvarsson and Bandurraga 1996, p. 21). This is consistent with the concept that some of the water moves laterally on top of the low-permeability zone before it resumes its downward course to the saturated zone.

DOE has recently undertaken development of what is termed an “expected-case” model of groundwater flow in the unsaturated zone as reported in DIRS 156609-BSC (2001, all). One of the objectives of this effort was to evaluate the impact of the conservatism in the Total System Performance Assessment (TSPA) modeling (see Chapter 5 and Appendix I). The study examined the flow and transport models used in the TSPA effort to identify areas where conservatism could be reduced and uncertainty better characterized. The result is a model of unsaturated zone flow that DOE believes is more realistic than the conservative one. The expected-case model was run under several varying conditions, including runs assuming a nonsorbing tracer, which moves like water, was released at the level of the proposed repository. The results indicate it would take in the range of 7,000 to 8,000 years for 50 percent of the tracer to reach the underlying water table (DIRS 156609-BSC 2001, Figure 6.5-29, p. 183). Some of the tracer would find its way to faster pathways to the water table; some would take longer to travel the distance. Several different conceptual models of groundwater movement in the unsaturated zone were integrated into runs of the numerical mode. DOE believes the most likely case, as described here, presents an estimate of groundwater travel time from the proposed repository to the water table that is a reasonable representation of what occurs in the natural setting.

Unsaturated Zone Groundwater Quality. DOE has analyzed water from the unsaturated zone, both pore water from the rock matrix and perched water, to obtain information on the mechanisms of recharge and the amount of connection between the two. The preceding sections discuss some of the relevant findings.

Table 3-14 summarizes the chemical composition of perched and pore water samples from the vicinity of Yucca Mountain.

Table 3-14. Water chemistry of perched and pore water samples in the vicinity of Yucca Mountain.[a]

Constituent	Ranges of chemical composition: Perched	Ranges of chemical composition: Pore
pH	7.6 - 8.7	7.7 - 8.4
Total dissolved solids (milligrams per liter)	140 - 330	320 - 360
Calcium (milligrams per liter)	2.9 - 45	1.1 - 62
Magnesium (milligrams per liter)	0 - 4.1	0 - 4.5
Potassium (milligrams per liter)	1.7 - 10	N/A[b]
Sodium (milligrams per liter)	34 - 98	49 - 140
Bicarbonate (milligrams per liter)	110 - 220	170 - 230
Chloride (milligrams per liter)	4.1 - 16	26 - 90
Bromide (milligrams per liter)	0 - 0.41	0
Nitrate (milligrams per liter)	0 - 34	11 - 17
Sulfate (milligrams per liter)	4 - 220	14 - 45

a. Source: DIRS 104951-Striffler et al. (1996, Table 2).
b. N/A = not available.

The smaller concentrations of dissolved minerals, particularly chloride, in perched water in comparison to those in pore water is a primary indicator of differences between the two. This difference in dissolved mineral concentrations indicates that the two types of water do not interact to a large extent and that the perched water reached its current depth with little interaction with rock. This, in turn, provides strong evidence that flow through faults and fractures is the primary source of the perched water (DIRS 151945-CRWMS M&O 2000, p. 5.4-2).

Saturated Zone

Water Occurrence. The saturated zone at Yucca Mountain has three aquifers and two confining units. The aquifers are commonly referred to as the upper volcanic aquifer, the lower volcanic aquifer, and the lower carbonate aquifer. The interlayered aquitards (low permeability units that retard water movement) that separate the aquifers are called the upper volcanic confining unit and the lower volcanic confining unit (see Figure 3-17). The upper volcanic aquifer is composed of the Topopah Spring welded tuff, which occurs in the unsaturated zone near the repository but is present beneath the water table to the east and south of the proposed repository. The upper volcanic confining unit includes the vitrophyre and nonwelded tuffs at the base of the Topopah Spring Tuff, the Calico Hills nonwelded unit, and the uppermost unstructured end of the Prow Pass tuff where they are saturated. The lower volcanic aquifer includes most of the Crater Flat Group, and the lower volcanic confining unit includes the lowermost Crater Flat Group and deeper tuff, lavas, and flow breccias. An upper carbonate aquifer, though regionally important, is not known to occur beneath Yucca Mountain. (The lower volcanic aquifer discussed here corresponds to the middle volcanic aquifer shown in Figure 3-17. The lower volcanic aquifer in Figure 3-17 has not been identified in the area of the proposed repository.)

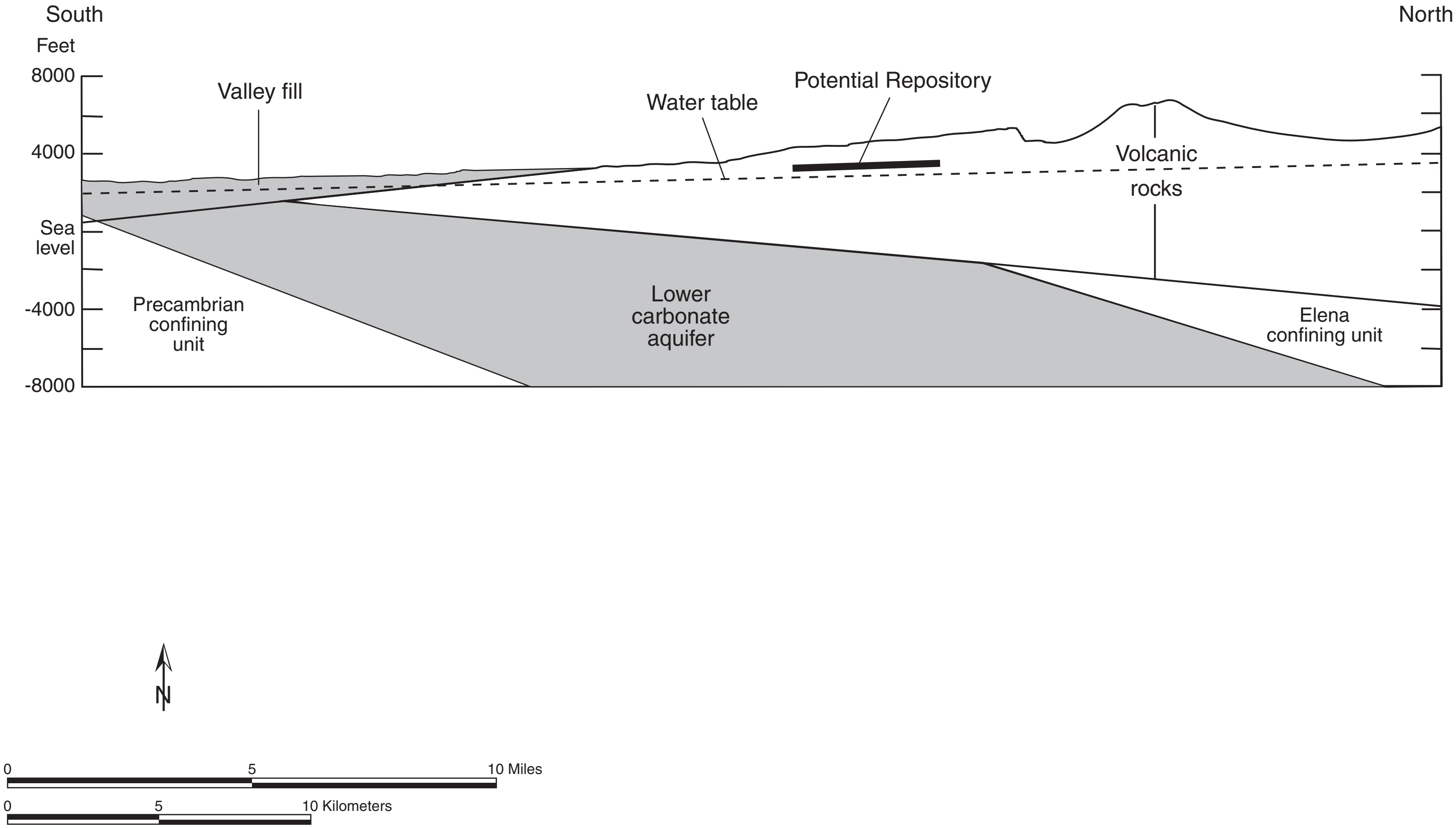
TYPES OF TUFF

Welded tuff results when the volcanic ash is hot enough to melt together and is further compressed by the weight of overlying materials.

Non-welded tuff results when volcanic ash cools in the air sufficiently that it does not melt together, yet later becomes rock through compression.

South of the proposed repository site, downgradient in the groundwater flow path from Yucca Mountain, the Tertiary volcanic rocks (and the volcanic aquifers) pinch out and groundwater moves into the valley-fill sediments of the Amargosa Desert (DIRS 151945-CRWMS M&O 2000, p. 9.3-80). Figure 3-18, which is a generalized hydrogeologic cross-section from Yucca Mountain to the northern portion of the Amargosa Desert, shows the relative positions of these aquifers. In the Amargosa Desert south of Yucca Mountain, the most important source of water is an aquifer formed by valley-fill deposits (DIRS 151945-CRWMS M&O 2000, p. 9.2-23).

The lower carbonate aquifer is more than 1,250 meters (4,100 feet) below the proposed repository horizon (DIRS 151945-CRWMS M&O 2000, Table 9.3-8, p. T9.3-10). This aquifer, which consists of lower Paleozoic carbonate rocks (limestone and dolomite) that have been extensively fractured during many periods of mountain building (see Section 3.1.3), forms a regionally extensive aquifer system through which large amounts of groundwater flow (DIRS 151945-CRWMS M&O 2000, p. 9.2-8). Evidence indicates that water in the lower carbonate aquifer is at least as old as most of the water in the volcanic aquifers (with apparent ages in the range of 10,000 to 20,000 years) (DIRS 151945-CRWMS M&O 2000, pp. 9.2-57 and 9.6-4) and, similarly, was recharged during a wetter and cooler climate (DIRS 151945-CRWMS M&O 2000, p. 9.6-4). Some of the limited carbonate aquifer sample results indicate older water ages (up to 30,000 years), but use of carbon-14 dating on this water has an additional limitation due to the probable contribution of “dead carbon” (nonradioactive) dissolved from the carbonate rock (DIRS 151945-CRWMS M&O 2000, p. 9.2-57).



Source: Modified from DIRS 151945-CRWMS M&O (2000, Figure 9.3-4, p. F9.3-4).

Figure 3-18. Cross section from Northern Yucca Mountain to Northern Amargosa Desert, showing generalized geology and the water table.

Limited data at Yucca Mountain show that the level to which water rises in a well that penetrates the lower carbonate aquifer is about 20 meters (66 feet) higher than the water levels in the overlying volcanic aquifers (DIRS 151945-CRWMS M&O 2000, p. 9.3-34). Four other wells at Yucca Mountain that penetrate as deep as the lower volcanic confining unit (the unit above the carbonate aquifer), show higher potentiometric levels in that unit than in overlying volcanic aquifers. This might be an indication of the upward hydraulic gradient in the carbonate aquifer (DIRS 100465-Luckey et al. 1996, p. 29). One of the wells for the Nye County Early Warning Drilling Program, which is about 19 kilometers (12 miles) south of the repository site, also penetrated the carbonate aquifer and shows it to have an upward gradient. At this location, water in the carbonate aquifer well rises 8 meters (26 feet) higher than the water level in the overlying volcanic aquifer (DIRS 155950-BSC 2001, pp. 12-12 and 12-13, and Figure 12.3.2-1, p. 12F-4). This indicates that, in the vicinity of Yucca Mountain, and in areas to the south, water from the lower carbonate aquifer is pushing up against a confining layer with more force than the water in the upper aquifers is pushing down. This suggests that water in the volcanic aquifers does not flow down into the lower carbonate aquifer at Yucca Mountain because it would be moving against a higher upward pressure and that, if mixing occurs, it would be from carbonate to volcanic and not the reverse.

Paleoclimatic (referring to the climate during a former period of geologic time) studies have identified five wetter and cooler periods in the southern Great Basin during the past 400,000 years (late Pleistocene). These periods occurred 10,000 to 50,000 years ago; 60,000 to 70,000 years ago; 120,000 to 170,000 years ago; 220,000 to 250,000 years ago; and 330,000 to 400,000 years ago. They represent the sequencing of glacial (cooler and wetter) to interglacial (warmer and drier) and back to glacial climates (DIRS 151945-CRWMS M&O 2000, p. 6.3-19). Calcite veins and opal were deposited along fractures during the wetter periods. The calcite and opal coatings have been dated by the uranium series method; the calcites have also been dated by the carbon-14 method. The youngest vein deposits are 16,000 years old (DIRS 151945-CRWMS M&O 2000, p. 6.3-33). During the wetter periods, the estimated regional water table was a maximum of 120 meters (390 feet) above the present level beneath Yucca Mountain during the past million or more years based on mineralogic, isotopic, and discharge deposit data and on hydrologic modeling analysis. The water table could rise by an estimated 50 to 130 meters (160 to 430 feet) from current levels under hypothetical future wetter climate conditions (DIRS 137917-CRWMS M&O 2000, p. 9.4-24). The proposed repository drift layouts would all be well above these historic and possible future maximum water table elevations (see Section 2.1). The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, pp. 6.3-1 to 6.3-39) provides additional information, including supporting evidence, on the timing, magnitude, and character of past climate changes in the Yucca Mountain region.

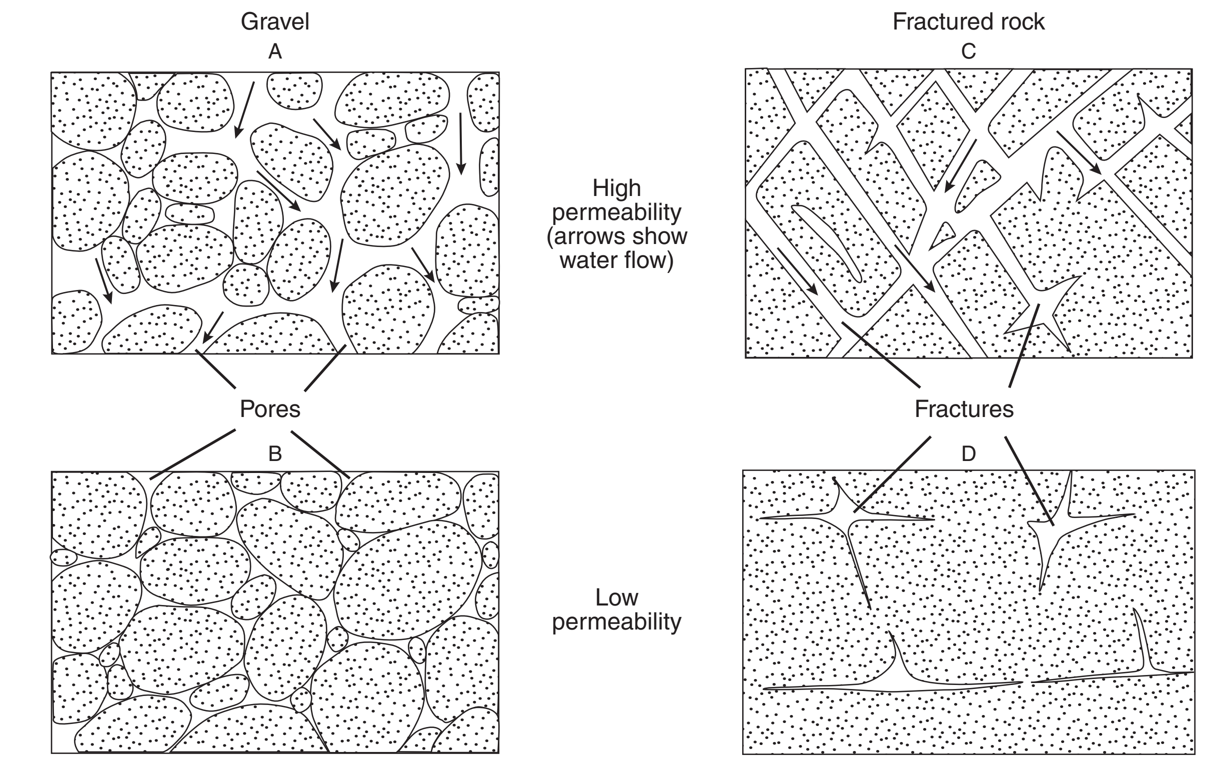
Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically higher than 120 meters (390 feet) above the current level, even reaching the land surface in the past (DIRS 106963-Szymanski 1989, all). If such an event occurred, it would affect the performance of the proposed repository. These concerns originated in the early- to mid-1980s when surface excavations performed as part of site investigations exposed vein-like deposits of calcium carbonate and opaline silica (DIRS 151945-CRWMS M&O 2000, p. 4.4-25). DIRS 106963-Szymanski (1989, all) hypothesized that the carbonate and silica were deposited by hydrothermal fluids, driven to the surface by pressurization of groundwater by earthquakes (a mechanism called *seismic pumping*) or by thermal processes that occurred in the Yucca Mountain vicinity. A number of investigators and groups, including a National Academy of Science panel specifically designated to look at the issue (DIRS 105162-National Research Council 1992, all), have examined the model on which this position is based and have rejected its important aspects (DIRS 100465-Luckey et al. 1996, pp. 76 to 77). The National Research Council panel concluded that the evidence cited as proof of groundwater upwelling in Yucca Mountain and in its vicinity could not reasonably be attributed to that process. In addition, the panel stated its position that the proposed mechanism for upwelling water was inadequate to raise the water table more than a few tens of meters (DIRS 101779-DOE 1998, Volume 1, p. 2-26). Finally, the panel concluded that the carbonate-rich depositions in fractures were formed from surface water from precipitation and surface processes (DIRS 151945-CRWMS M&O 2000, p. 4.4-36).

Another alternative interpretation of past groundwater levels at Yucca Mountain occurs in DIRS 104875-Dublyansky (1998, all). This study involved the examination of tiny pockets of water (known as *fluid inclusions*) trapped in the carbonate-opal veinlets deposited in rock fractures at Yucca Mountain. According to the report, an analysis of samples collected from the Exploratory Studies Facility includes evidence of trace quantities of hydrocarbons and evidence that the fluid inclusions were formed at elevated temperatures. These findings, and others, are used to support the report's conclusion that the carbonate-opal veinlets were caused by warm upwelling water and not by the percolation of surface water. DOE, given the opportunity to review a preliminary version of the report, arranged for review by a group of independent experts, including U.S. Geological Survey personnel and a university expert. This review group did not concur with the conclusion in the report by DIRS 104875-Dublyansky (1998, all), which now contains an appendix with the DOE-arranged review comments and the author's responses. Although DOE disagreed with some of the central scientific conclusions presented in this report, both parties agreed that additional research was needed to resolve the issue. As a result, DOE supported an independent investigation by the University of Nevada at Las Vegas, in which both the U.S. Geological Survey and the State of Nevada were invited to participate. This independent effort to analyze mineral samples from Yucca Mountain is not yet final, but University researchers presented papers on their preliminary findings at a November 2000 meeting of the Geological Society of America. They reported (DIRS 154280-Wilson et al. 2000, all) that evidence was present of fluid inclusions being formed at elevated temperature, but generally in the older (basal) part of the samples. Uranium-lead dating of the minerals in the younger outer surfaces, where there was no such evidence, indicates these minerals began precipitating between 3.8 and 1.9 million years ago. As a result, the study concluded that passage of fluids with elevated temperatures occurred prior to that time.

Opposing viewpoints dealing with the analysis of mineral samples from Yucca Mountain were presented at the same meeting of the Geological Society of America. One paper (DIRS 154790-Pashenko and Dublyansky 2000, all) reiterated the position that the apparent deposition temperatures of fluid inclusions were simply too high to be attributed to descending rainwater. Another (DIRS 154789-Dublyansky 2000, all) pointed to the diversity in the make-up of the mineral deposits as another piece of evidence suggesting a low-temperature hydrothermal (upwelling) origin. DOE and the State of Nevada are continuing to evaluate these and other alternative conceptual models and data interpretations.

Hydrologic Properties of Rock. This section discusses the hydrologic properties of rock in the saturated zone, and specifically the aquifers and confining units at Yucca Mountain. As discussed above, these properties depend in part on whether the rocks are saturated. In general, the amount and speed at which water flows through an aquifer depend chiefly on the transmissivity and effective porosity of the rock. *Transmissivity* is a measure of how much water an aquifer can transfer and is equal to the average hydraulic conductivity of the aquifer multiplied by the thickness of the aquifer that is saturated. *Hydraulic conductivity* is the volume of water moving in an aquifer during a unit of time through a unit of area that is perpendicular to the direction of flow. *Porosity* is the ratio of the rock's void (open) space to its total volume; *effective porosity* is the ratio of interconnected void space to total volume.

Figure 3-19 shows the types of conditions that might exist in gravel and rock aquifers that would make them more or less permeable to water movement. The empty spaces between gravel fragments or in the rock fractures represent the porosity. Although not necessarily representative of conditions at Yucca Mountain, the figure shows that the manner in which void spaces are interconnected, more than their size or quantity, determines how water can move through the material. At Yucca Mountain, conditions are often such that the rock with the highest porosity is also the rock with the fewest fractures (DIRS 151945-CRWMS M&O 2000, p. 9.2-7). Because the void spaces are not interconnected very well, such a high-porosity rock has low transmissivity. Because a large portion of the groundwater flow at Yucca Mountain



A. Gravel with interconnected pore space having relatively high permeability.
B. Gravel with limited interconnected pore space having relatively low permeability.
C. Rock with interconnected fractures having relatively high permeability.
D. Rock with few interconnected fractures having relatively low permeability.

Source: Modified from DIRS 103473 - USGS (1993, page 2).

Figure 3-19. Aquifer porosity and effects on permeability.

is probably along fractures, representative transmissivity values are difficult to measure. Measurements can vary greatly depending on the nature of the fractures that happen to be intercepted by the borehole and the location in the borehole at which measurements are made. This is reflected in the wide range of transmissivity values listed in Table 3-15, which also lists the characteristics, thicknesses, apparent hydraulic conductivities, and porosities of the three aquifers and two confining units beneath Yucca Mountain. For the lower carbonate aquifer, the table lists a single transmissivity value because there was only a single test for that unit. Similarly, only one apparent hydraulic conductivity value, which is a measure of the aquifer's capacity to transport water, is provided for the lower carbonate aquifer unit because it is based on tests in a single well at Yucca Mountain. However, the value is an average of measurements taken from that well. This and the other hydraulic conductivity values are called *apparent* because they are all based on single-borehole tests. Such measurements, which are believed to represent conditions at a limited distance around the well, could vary greatly depending on whether there are water-bearing fractures in the well zone being tested. When such fractures are present, hydraulic properties measured in a single-borehole test probably reflect conditions only in isolated locations rather than in the overall rock matrix in the test zone.

Water Source and Movement. Section 3.1.4.2.1 describes the direction of water movement (Figure 3-15), the nature of the rock through which it moves, and where local recharges to and discharges from the aquifer might occur.

When undisturbed by pumping, groundwater levels at Yucca Mountain have been very stable. A Geological Survey study of water levels over 10 years (1985 to 1995) indicated water levels did not change by season and most water-level fluctuations are probably due to changes in barometric pressure

Table 3-15. Aquifers and confining units in the saturated zone at Yucca Mountain.

Unit	Typical thickness (meters)[a,b,c]	Transmissivity (square meters per day)[d,e]	Apparent hydraulic conductivity (meters per day)[e]	Typical porosity[f,g] (ratio)
Upper volcanic aquifer Densely welded and densely fractured part of Topopah Spring Tuff	300	120 - 1,600	0.13 - 19	0.05 - 0.10
Upper volcanic confining unit Basal vitrophyre of Topopah Spring Tuff, Calico Hills Formation Tuff, and uppermost nonwelded part of Prow Pass Tuff	90 - 330	2.0 - 26	0.02 - 0.26	0.l9 - 0.28
Lower volcanic aquifer Most of Prow Pass Tuff and underlying Bullfrog and Tram Tuffs of Crater Flat Group	370 - 700	1.1 - 3,200	< 0.0037 - 13	0.19 - 0.24
Lower volcanic confining unit Bedded tuffs, lava flows, and flow breccia beneath Tram Tuff	370 - > 750	0.003 - 23	5.5×10^{-6} - 0.11	0.15 - 0.24
Lower carbonate aquifer Cambrian through Devonian limestone and dolomite	N/A[h]	120	0.19	0.003 - 0.05

a. Source: DIRS 100465-Luckey et al. (1996, Table 2 and Figure 7).
b. To convert meters to feet, multiply by 3.2808.
c. Typical thickness ranges for the upper volcanic confining unit, the lower volcanic aquifer, and the lower volcanic confining unit are based on measurements from 13 boreholes. With respect to the lower volcanic confining unit, only one penetrated and showed a unit thickness of about 370 meters (1,200 feet); of the others, about 750 meters (2,500 feet) was the deepest penetration without passing through. Water was detected in the rock unit that elsewhere makes up the upper volcanic aquifer unit in only one of the 13 boreholes. (Beneath the center of Yucca Mountain, the upper volcanic aquifer is above the saturated zone.) The typical thickness shown here for this unit is based on Figure 7 from DIRS 100465-Luckey et al. (1996, Figure 7).
d. To convert square meters to square feet, multiply by 10.764.
e. Source: DIRS 151945-CRWMS M&O (2000, Tables 9.3-4 and 9.3-5, pp. T9.3-6 and T9.3-7).
f. Source: DIRS 151945-CRWMS M&O (2000, pp. 9.3-10 to 9.3-17).
g. Ranges are for means of several hydrogeological subunits.
h. N/A = not available.

and Earth tides (DIRS 151945-CRWMS M&O 2000, p. 9.3-30). In addition, short-term fluctuations in groundwater elevations also have been attributed to apparent recharge events and earthquakes. Water levels in wells have fluctuated by as much as 0.9 meter (3 feet) in response to earthquake events, and confined water pressure deep in wells fluctuated by as much as 2.2 meters (7 feet) in response to those same events. However, the fluctuations are typically of short duration with water levels returning to the pre-earthquake conditions within minutes to a few hours (DIRS 151945-CRWMS M&O 2000, pp. 9.4-20 and 9.4-21). An exception to this occurred in response to earthquakes in the summer of 1992, when water levels in specific wells at Yucca Mountain fluctuated over several months.

At the northern end of Yucca Mountain, the apparent potentiometric surface slopes steeply southward, dropping almost 300 meters (980 feet) in a horizontal distance of about 2 kilometers (1.2 miles) (DIRS 151945-CRWMS M&O 2000, pp. 9.2-46 and 9.3-31). Experts reviewing the data have suggested several credible reasons for this large gradient, including that it results from an undetected geological feature with low permeability, that it is caused by groundwater draining to deep aquifers, or that it is a perched water table being encountered in this area (DIRS 100353-CRWMS M&O 1998, pp. 3-5 and 3-6). However, there are no obvious geologic reasons for the large gradient, and it is still under investigation.

The north-trending Solitario Canyon fault, on the west side of Yucca Mountain, apparently impedes the eastward flow of groundwater in the saturated zone. West of the fault, the water table slopes moderately about 40 meters (130 feet) in less than 1 kilometer (0.6 mile), while east of the fault the water table slopes very gently, changing by only 0.1 to 0.3 meter per kilometer (0.5 to 1.6 feet per mile) (DIRS 151945-CRWMS M&O 2000, pp. 9.3-38 to 9.3-40, and Figure 9.3-15, p. F9.3-15). West of the Solitario Canyon fault groundwater probably flows southward either along the fault or beneath Crater Flat.

The gentle southeastward groundwater gradient east of the Solitario Canyon fault underlies the proposed repository horizon and extends beneath Fortymile Wash and probably farther east into Jackass Flats. This gentle gradient might indicate that the rocks through which the water flows are highly transmissive, that only small amounts of groundwater flow through this part of the system, or a combination of both. This gentle southeastward gradient is a local condition in the regional southward flow of the groundwater.

In an opposing viewpoint about the stability of groundwater levels at Yucca Mountain, DIRS 103180-Davies and Archambeau (1997, pp. 33 and 34) suggests that a moderate magnitude earthquake at the site could cause a southward displacement of the large hydraulic gradient to the north of the proposed repository, resulting in a water table rise of about 150 meters (490 feet) at the site. In addition, that report proposed that a severe earthquake could cause a rise of about 240 meters (790 feet) in the water table, flooding the repository. As part of its study of groundwater flow in the saturated zone, DOE elicited expert opinions on various issues from a panel of five experts in the fields of groundwater occurrence and flow. Among the issues put to the panel were those raised by DIRS 103180-Davies and Archambeau (1997, all). The panel reviewed the Davies and Archambeau paper and received briefings by project personnel and outside specialists. The consensus of the panel was that a rise of the groundwater to the level of the proposed repository was essentially improbable and that changes to the water table associated with earthquakes would be neither large nor long-lived (DIRS 100353-CRWMS M&O 1998, p. 3-14).

Inflow to Volcanic Aquifers at Yucca Mountain. There are four potential sources of inflow to the volcanic aquifers in the vicinity of Yucca Mountain: (1) lateral flow from volcanic aquifers north of Yucca Mountain, (2) recharge along Fortymile Wash from occasional stream flow, (3) precipitation at Yucca Mountain, and (4) upward flow from the underlying carbonate aquifer. The actual and relative amounts of inflow from each source cannot be measured directly on any large-scale basis. However, estimates have been generated based on data collected and tests performed at individual locations and from incorporation of these data into regional- and site-scale models of the unsaturated and saturated zones.

North of Yucca Mountain, the potentiometric surface rises steeply toward probable recharge areas on Pahute Mesa (Figure 3-15) and Rainier Mesa. Chemical data indicate that some recharge to the groundwater has occurred everywhere in the Yucca Mountain vicinity during the past 10,000 years, but that most recharge occurred between 10,000 and 20,000 years ago (based on apparent carbon-14 ages) during a wetter climate (DIRS 151945-CRWMS M&O 2000, p. 9.3-53). From west to east across Yucca Mountain, the age of water in the saturated zone decreases from about 19,000 years to 9,100 years (DIRS 101036-Benson and McKinley 1985, p. 4).

One estimate of the annual recharge along a 42-kilometer (26-mile) segment of Fortymile Wash in the area of Yucca Mountain is about 110,000 cubic meters (88 acre-feet) (DIRS 151945-CRWMS M&O 2000, pp. 7.2-1 and 7.2-2). Much of the recharge occurs during and after heavy precipitation when water flows in the wash. On rare occasions, Fortymile Wash carries water to Jackass Flats and into the Amargosa Desert. After periods of flow in Fortymile Wash during 1983, 1992, 1993, and 1995 water levels in nearby wells rose as a result of infiltration (DIRS 151945-CRWMS M&O 2000, p. 7.2-2). Earlier studies found that shallow water in some wells was younger than water deeper in the wells, indicating that recharge was occurring (DIRS 151945-CRWMS M&O 2000, p. 9.3-53). Paleoclimatic evidence suggests that perennial water was present in Fortymile Wash 50,000 years ago (DIRS 105162-National Research Council 1992, Appendix C, p. 198), and that substantial recharge might have occurred as recently as 7,000 to 15,000 years ago (DIRS 151945-CRWMS M&O 2000, p. 9.3-53).

Recharge to the saturated zone below Yucca Mountain from precipitation is small in comparison to inflow from volcanic aquifers to the north or recharge along Fortymile Wash (see the unsaturated zone discussion). An average net infiltration of 4.7 millimeters (0.2 inch) over a 4.7-square-kilometer (1.8-square-mile) repository footprint would produce a quantity of recharge about 20 percent of the estimated annual recharge along the nearby 42-kilometer (26-mile) segment of Fortymile Wash.

Monitoring well data collected during the site characterization effort have shown that the potentiometric surface of the carbonate aquifer (that is, the level to which water rises in wells tapping this aquifer), at least in the immediate vicinity of Yucca Mountain, is higher than the water level in the overlying volcanic aquifer. Based on this and other considerations, studies suggest that, provided structural pathways exist, the lower carbonate aquifer might provide upward flow to the volcanic aquifer beneath the proposed level of the repository and farther south. The amount of inflow, if it occurs, is not known.

Outflow from Volcanic Aquifers at and Near Yucca Mountain. Pathways by which water might leave the volcanic aquifers in the Yucca Mountain vicinity include (1) downgradient movement into other volcanic aquifers and alluvium in the Amargosa Desert, (2) downward movement into the carbonate aquifer (though evidence indicates that this does not occur), and (3) upward movement into the unsaturated zone. In addition, water is pumped from wells for a variety of uses, as described in Section 3.1.4.2.1. With the exception of well withdrawals, the actual and relative amounts of outflow from each source are not known.

The regional slope of the potentiometric surface indicates that much of the groundwater flowing southward beneath Yucca Mountain discharges about 60 kilometers (37 miles) to the south at Alkali Flat (Franklin Lake Playa) and in Death Valley. Death Valley, more than 80 meters (260 feet) below sea level, is the final sink for surface water and groundwater in the Death Valley regional groundwater flow system (Figure 3-13); as such, water leaves only by evapotranspiration. Therefore, the pathway for groundwater beneath Yucca Mountain, as indicated by the potentiometric surface, is southerly where it traverses portions of the volcanic aquifers before encountering the basin-fill alluvium and carbonate rock that underlie the Amargosa Desert.

Outflow from the volcanic aquifers into the underlying carbonate aquifer might occur, but direct evidence for this does not exist. Studies suggest that the steeply sloping potentiometric surface at the north end of Yucca Mountain could be explained by a large outflow from the volcanic aquifers to the carbonate aquifer. However, in the vicinity of Yucca Mountain, data available on the potentiometric head of the carbonate aquifer indicate that the opposite condition (that is, outflow from the carbonate aquifer up to the volcanic aquifer) is more likely.

The third possible pathway of outflow from the volcanic aquifer (that is, upward movement to the unsaturated zone), if present, has not been quantified. However, consistent with the above discussion of net infiltration, DOE believes that there is a net downward movement of water in the unsaturated zone in the vicinity of Yucca Mountain.

Use. Two wells, J-12 and J-13 (shown in Figure 3-20), are part of the water system for site characterization activities at Yucca Mountain. These are the nearest production wells to Yucca Mountain and they support water needs for Area 25 of the Nevada Test Site and for Exploratory Studies Facility activities. Both of these wells withdraw groundwater from the Jackass Flats hydrographic area, as listed in Table 3-11. Groundwater has also been pumped from the Jackass Flats area from various boreholes for hydraulic testing, and most recently from the C-well complex, which consists of three separate wells grouped in an area just east of the South Portal Development Area (DIRS 100465-Luckey et al. 1996, Figure 17). In addition, water has been pumped occasionally from borehole USW VH-1 (also designated CF-2) in support of Yucca Mountain characterization activities. But the volume pumped from this well, which is in the Crater Flat hydrographic area, is small (DIRS 100465-Luckey et al. 1996, p. 70).

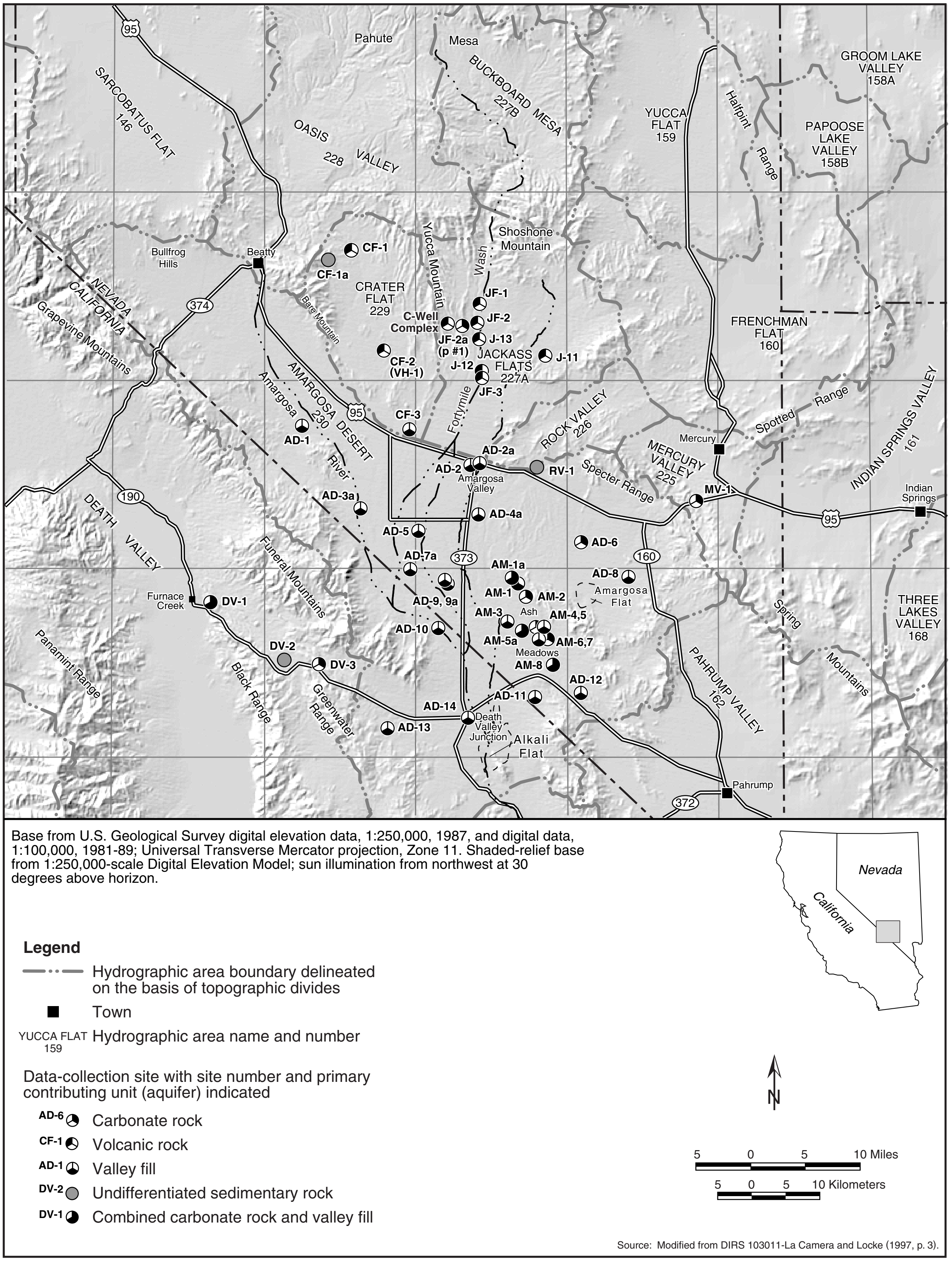


Figure 3-20. Selected groundwater data-collection sites in the Yucca Mountain region.

The Yucca Mountain Site Characterization Project has received water appropriation permits (Numbers 57373, 57374, 57375, and 57376) from the State of Nevada for wells J-12, J-13, VH-1 (also known as CF-2), and the C-Well complex (Numbers 58827, 58828, and 58829), and a Potable Water Supply permit (NY-0867-12NCNT) for the distribution system. The permits allow a maximum pumping rate of about 0.028 cubic meter (1 cubic foot) a second, with a maximum yearly withdrawal of about 530,000 cubic meters (430 acre-feet) (DIRS 151945-CRWMS M&O 2000, p. 9.5-3 and 9.5-4, and Table 9.5-3, p. T9.5-3). The permit limits apply to site characterization water use. Table 3-16 lists historic and projected water use from wells J-12 and J-13 from 1992 to 2005 for the Exploratory Studies Facility and Concrete Batch Plant, and from the C-Wells, which is pumped and then reinjected as part of aquifer testing. It also lists the total amount of water pumped from wells J-12 and J-13 for both Yucca Mountain and the Nevada Test Site. The difference between the quantities pumped from wells J-12 and J-13 for Yucca Mountain activities and the total withdrawals from these wells represents the quantities used for Nevada Test Site activities in the area. The water-use projections in Table 3-16 are through the end of site characterization activities; Section 4.1.3 discusses water demand projections for the proposed repository.

Table 3-16. Water withdrawals (acre-feet)[a] from wells in the Yucca Mountain vicinity.

Year	J-12 and J-13 Yucca Mountain characterization[b]	J-12 and J-13 total withdrawals[c]	C-wells[b]
1992	18	120	0
1993	80	210	0
1994	75	280	0
1995	94	260	19
1996	66	220	180
1997	63	150	190
1998	63[d]	N/A[e]	190[f]
1999	63	N/A	N/A
2005	63	N/A	N/A

a. To convert acre-feet to cubic meters, multiply by 1233.49.
b. Source: DIRS 104988-CRWMS M&O (1999, p. 4).
c. Source: DIRS 103171-Clary et al. (1995, p. 660); DIRS 101486-Bauer et al. (1996, p. 702); DIRS 103090-Bostic et al. (1997, p. 592); DIRS 103082-Bonner et al. (1998, p. 606); DIRS 103283-La Camera, Locke, and Munson (1999, all); withdrawals for 1992 and 1993 were estimated from figures in DIRS 103011-La Camera and Locke (1997, p. 51).
d. Assumed to remain constant from 1997 through 2005.
e. N/A = not available.
f. Assumed to remain constant from 1997 to 1998.

The U.S. Geological Survey, in support of Yucca Mountain characterization efforts and in compliance with the State permits, has kept records of the amount of water pumped from the J-12 and J-13 wells and of measured water elevation levels in those and other wells in their immediate area since 1992 (DIRS 103011-La Camera and Locke 1997, pp. 1 and 2). One of the objectives of keeping these records is to detect and document changes in groundwater resources during the Yucca Mountain investigations. Therefore, the Survey effort included the collection of historic water elevation data to establish a baseline. Results from these efforts have been documented in annual reports. The report for 1997 (DIRS 103283-La Camera, Locke, and Munson 1999, all) includes a summary of 1996 results and detailed results for 1997. Table 3-17 summarizes the changes observed in median groundwater elevations in seven wells in Jackass Flats. The second column of the table identifies the historic or baseline elevation for each well against which the annual median values are being compared. In addition, the table lists the average deviation of measured water levels during the period from which the baseline was generated.

Table 3-17. Differences between annual median elevations and baseline median elevations.[a]

Well	Baseline elevations: Median (meters[c] above sea level)	Baseline elevations: Average deviation about the median (centimeters)	Difference (in centimeters[b]) baseline: 1992	1993	1994	1995	1996	1997
JF-1	729.23	± 6	–3	0	–6	0	–6	–3
JF-2	729.11	± 9	+3	0	+3	+9	0	–3
JF-2a[d]	752.43	± 12	0	+6	+12	+15	+21	+27
J-13	728.47	± 6	–3	–3	–9	–6	–12	–12
J-11	732.19	± 3	0	0	+3	+6	+6	+12
J-12	727.95	± 3	0	0	–3	–3	–9	–9
JF-3	727.95	± 3	N/A[e]	N/A	–6	–6	–9	–9

a. Source: DIRS 103283-La Camera, Locke, and Munson (1999, Table 10).
b. To convert centimeters to inches, multiply by 0.3937.
c. To convert meters to feet, multiply by 3.2808.
d. Well JF-2a is also known as UE-25 p#1, or P-1.
e. N/A = not available.

The elevation changes listed in Table 3-17 are different from the short-term fluctuations described above that are a response to changes in barometric pressure and Earth tides. The differences in comparison of annual median values should indicate water level trends, if there are any. The data show that a decline in groundwater elevation has been seen in some, but not all, of the local wells. Specifically, the data show the following:

- Two wells, JF-1 and JF-2, stayed within the band of elevations characteristic of the baseline data.
- Two wells, JF-2a (also known as UE-25 p#1, or P-1) and J-11, indicated elevation increases of 15 and 9 centimeters (about 5.9 and 3.5 inches), respectively, above the band of elevations characteristic of the baseline data (and even higher above the median of the baseline data as listed in the table).
- Three wells, J-13, J-12, and JF-3, each indicated an elevation decrease of 6 centimeters (about 2.4 inches) below the band of elevations characteristic of the baseline data (and even further below the median of the baseline data as listed in the table).

In its discussion of groundwater levels, the U.S. Geological Survey (DIRS 103011-La Camera and Locke 1997, p. 22) indicated that monitoring of water levels in the seven wells should continue to see if additional decreases occur and if they can be correlated to periods of withdrawal. In regard to overall groundwater levels in the Jackass Flats area, the data do not appear to show any definitive trend in elevation change, either up or down. However, the three wells showing a water decline are either being pumped (J-12 and J-13) or, in the case of JF-3, are close to a production well. Of the two wells (JF-2a and J-11) showing water-level increases, one (JF-2a) penetrates the lower carbonate aquifer and the other, though penetrating a volcanic aquifer, is farthest from the production wells of any shown on the table. Pumping from the volcanic aquifer production wells would be unlikely to affect either of these wells. There is some speculation that the consistent water-level increase over time in well JF-2a might indicate that it has not yet reached an *equilibrium* elevation.

Saturated Zone Groundwater Quality. Groundwater quality for the aquifers beneath Yucca Mountain was addressed by the Geological Survey sampling and analysis effort described above for regional groundwater quality. This effort included the collection and analysis of samples from three wells in the Jackass Flats area (including J-12 and J-13); the results indicated that the concentrations of dissolved substances in local groundwater were below the numerical criteria of the primary drinking water standards set by the Environmental Protection Agency for public drinking water systems (DIRS 104828-Covay 1997, all). However, samples from each of the wells exceeded the secondary standard for fluoride, as they did for a proposed standard for radon. Both of these constituents occur naturally in the rock through which the groundwater flows. Overall, local groundwater quality is generally good.

Investigations of the chemical and mineral composition of groundwater at Yucca Mountain have provided an indication of the differences between the aquifers beneath the site. The chemical composition of groundwater depends on the chemistry of the recharge water and the chemistry of the rocks through which the water travels. Water in the volcanic aquifers and confining units at Yucca Mountain has a relatively dilute sodium-potassium-bicarbonate composition that probably results from the *dissolution* of volcanic tuff (Table 3-18). The chemistry of water from the lower carbonate aquifer is very different (a generally more concentrated calcium-magnesium-bicarbonate composition), which would be expected from water traveling through and dissolving carbonate rock (Table 3-18).

Table 3-18. Water chemistry of volcanic and carbonate aquifers at Yucca Mountain (milligrams per liter).[a]

	Chemical composition	
Chemical constituent	Volcanic aquifers[b]	Lower carbonate aquifer[c]
Calcium	1.4 - 37	100
Magnesium	< 0.01 - 10	39
Potassium	1.1 - 5.6	12
Sodium	38 - 120	150
Bicarbonate	110 - 282	569
Chloride	5.5 - 13	28
Sulfate	16 - 45	160
Silica	40 - 57	41

a. Source: DIRS 101036-Benson and McKinley (1985, Table 1, p. 5).
b. Based on samples from 14 wells.
c. Based on samples from one well.

As part of the Yucca Mountain project, well and spring monitoring activities performed during 1997 aided the establishment of a baseline for radioactivity in groundwater near the site of the proposed repository (DIRS 104963-CRWMS M&O 1998, all). The quarterly sampling included six wells and two springs that were selected to ensure that at least two were representative of each of the three general aquifers (carbonate, volcanic, and alluvial) in the region. Samples were analyzed for gross alpha, gross beta, total uranium, and concentrations of selected beta and gamma-emitting radionuclides. Table 3-19 lists the results from this monitoring as average values from the quarterly sampling events for each well or spring. The table lists the location of each well or spring, including the data collection site designations shown on Figure 3-20, the contributing aquifer, and a comparison, if applicable, to *Maximum Contaminant Levels* established by the Environmental Protection Agency for water supplied by public drinking water systems. As indicated in the table, the sites sampled include locations outside the Alkali Flat-Furnace Creek groundwater basin in which Yucca Mountain is located. The Cherry Patch location is in the Ash Meadows groundwater basin and Crystal Pool and Fairbanks Spring are on the border between the two basins, but are fed by flow through Ash Meadows. The location variety supports area comparisons as well as comparisons between the different contributing aquifers.

Table 3-19 indicates that Maximum Contaminant Levels for combined radium-226 and radium-228 and for gross alpha were not exceeded by the average values from any of the sampling sites or by the maximum values reported for those parameters (DIRS 104963-CRWMS M&O 1998, pp. 12 to 21). The samples were analyzed for other beta- or gamma-emitting radionuclides, specifically tritium, carbon-14, chlorine-36, nickel-59, strontium-89, strontium-90, technetium-99, iodine-129, and cesium-137. The table does not list the results for these parameters because they are below minimum detectable activity (DIRS 104963-CRWMS M&O 1998, p. 13). As a conservative measure, however, DOE used the values reported by the laboratory to calculate dose contributions (DIRS 104963-CRWMS M&O 1998, Appendix F). Water from each sampling location was shown to have exposure values well below the 4-millirem-per-year total body (or any internal organ) dose limit set as the Maximum Contaminant Level for beta- or gamma-emitting radionuclides.

Table 3-19. Results of 1997 groundwater sampling and analysis for radioactivity.[a]

Site name and location description[b]	Contributing aquifer	Average combined radium-226 and -228 (picocuries per liter)	Average gross alpha (picocuries per liter)	Average total uranium[c] (micrograms per liter)	Average gross beta (picocuries per liter)	Average radon-222 (picocuries per liter)
J-12 and J-13[d] Fortymile Wash, SE of Yucca Mtn.	Volcanic	0.32±0.24	BDL[e]	0.52±0.03	6.04±0.60	384
C-3 (C-well complex) By South Portal, SE of Yucca Mtn.	Volcanic	0.58±0.36	1.34±1.05	1.04±0.09	3.59±0.76	763
Crystal Pool (Spring) (AM-5a) Ash Meadows	Carbonate/ alluvial[f]	0.93±0.20	BDL	2.64±0.23	14.0±1.28	447
Fairbanks Spring (AM-1a) Ash Meadows	Carbonate/ alluvial	0.80±0.36	BDL	2.23±0.19	11.1±1.17	279
Nevada Department of Transportation Well (AD-2a) Amargosa Valley	Alluvial	0.32±0.33	BDL	2.55±0.22	5.95±0.93	612
Gilgans South Well (AD-9a) Amargosa Desert	Alluvial	0.19±0.31	BDL	0.63 ± 0.05	9.14±0.97	600
Cherry Patch Well (AD-8) NE of Ash Meadows	Alluvial	0.22±0.33	9.19±4.35	13.1 ± 1.16	18.7±1.65	504
Drinking water Maximum Contaminant Levels[g]		5	15	NA[h]	NA	300 (proposed)

a. Source: DIRS 104963-CRWMS M&O 1998, pp. 12 to 21) for all but radon-222 data; DIRS 104828-Covay (1997, Table 4) for radon data.
b. Figure 3-20 shows the locations of the wells.
c. To convert total uranium concentrations in micrograms per liter to picocuries per liter, multiply by 0.68 (DIRS 104963-CRWMS M&O 1998, p. 15).
d. Average of data presented for Well J-12 and Well J-13.
e. BDL = below detection limit.
f. Alluvium is also identified as valley fill in DIRS 151945-CRWMS M&O (2000, p. 9.2-23).
g. Drinking water Maximum Contaminant Levels are set by the Environmental Protection Agency in 40 CFR Part 141.
h. NA = not applicable.

There is no indication that DOE activities at the Nevada Test Site have contaminated the groundwater beneath Yucca Mountain. This is consistent with studies performed on the Nevada Test Site. DIRS 103411-Nimz and Thompson (1992, all) documented about a dozen instances in which radionuclides have migrated into the groundwater from areas of nuclear weapons testing at the Nevada Test Site in 40 years. The maximum distance of tritium migration is believed to be several kilometers; less mobile radioactive constituents, which include a wide variety of isotopes (DIRS 101811-DOE 1996, pp. 4-126 to 4-129), have migrated no more than about 500 meters (1,600 feet). There has, however, been recent evidence of plutonium migration from one below-groundwater test at Pahute Mesa.

Groundwater monitoring results indicate plutonium has migrated at least 1.3 kilometers (0.8 mile) from this site in 28 years and is apparently associated with the movement of very small particles called colloids (DIRS 103282-Kersting et al. 1999, p. 56). None of the nuclear testing occurred in Area 25 where the Yucca Mountain Repository facilities would be. However, the flow of groundwater from areas on Pahute and Buckboard Mesas where DOE conducted 81 and 2 nuclear tests, respectively, could be to the south toward Yucca Mountain. The distance is about 40 kilometers (25 miles) to Pahute Mesa and about 30 kilometers (19 miles) to Buckboard Mesa (Figure 3-20). Because of these distances, there is no reason to believe that radionuclides from nuclear tests could migrate as far as Yucca Mountain during the active life (construction, operation and monitoring, and closure phases) of the repository, with the possible exception of tritium. Conservative modeling performed by DOE at the Nevada Test Site (DIRS 103021-DOE 1997, pp. ES-27 to ES-29, and ES-36) shows that tritium, moving with little or no attenuation in groundwater other than decay, could move to locations at or near Nevada Test Site boundaries in tens of years. However, the same study reports that monitoring has not shown tritium to be moving as rapidly as predicted when using the conservative assumptions of the model. In addition, the flow paths from the underground nuclear testing areas, as predicted in this study, do not intersect groundwater beneath Yucca Mountain. Chapter 8 discusses the potential for long-term migrations of radionuclides to result in cumulative radiation from nuclear testing contamination eventually migrating through the groundwater system and joining groundwater beneath the repository.

3.1.5 BIOLOGICAL RESOURCES AND SOILS

The region of influence for biological resources and soils is the area that contains all potential surface disturbances that would result from the Proposed Action plus some additional area to evaluate local animal populations. This region is roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (230 square miles). DOE used available information and studies on plants and animals at the site of the proposed repository and the surrounding region to identify baseline conditions for biological resources. This information included land cover types, vegetation associations, and the distribution and abundance of plant and animal species in the region of influence (the analyzed land withdrawal area) and in the broader region. The plants and animals in the Yucca Mountain region are typical of species in the Mojave and Great Basin Deserts.

DOE has surveyed the region for naturally occurring wetlands and has studied soil characteristics (thicknesses, water-holding capacity, texture, and erosion hazard) in the region. This section summarizes this information and describes existing soil conditions in relation to potential contaminants. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, all) or the *Environmental Baseline File for Soils* (DIRS 104592-CRWMS M&O 1999, all).

The State of Nevada (DIRS 148188-Loux 1997, all) expressed the view that there was no systematic integrated environmental program to characterize the unique and fragile desert environment at Yucca Mountain before 1982, when DOE began site investigation that may have caused irreversible alterations (DIRS 103298-Lemons and Malone 1989, pp. 435 to 441). However, the State acknowledged that after site investigations started and impacts might have occurred, DOE began studies of sensitive species, archaeology, airborne particulates, and groundwater (DIRS 103298-Lemons and Malone 1989, pp. 435 to 441), and established an environmental baseline from these data (DIRS 103396-Malone 1989, pp. 77 to 95). DIRS 103398-Malone (1995, pp. 271 to 284) contended that many of the studies conducted to establish the baseline and evaluate impacts, particularly those on plants and animals, were not adequately designed and did not use an integrated ecosystem approach and, therefore, were of little value for evaluating impacts of the repository.

DOE contends that studies initiated after the start of site investigations are suitable for establishing the baseline needed for this EIS. The purpose of studies of the impacts of site characterization activities on plants and animals was not to evaluate potential impacts from a repository, but rather to focus on the appropriate level of ecological organization for the types of impacts that occurred during characterization activities. DOE used the results of those studies in the EIS analysis to understand and predict possible impacts from similar activities that would occur during repository construction and operation (for example, habitat destruction).

3.1.5.1 Biological Resources

3.1.5.1.1 *Vegetation*

DOE adapted broad categories of land cover types for the analyzed land withdrawal area (based primarily on predominant vegetation; see Figure 3-21) from two sources: a statewide classification and a detailed, field-validated classification of the area surrounding the location of the proposed repository. Land cover types typical of the Mojave and Great Basin Deserts occur in the analyzed land withdrawal area; they include creosote-bursage (56 percent), blackbrush (14 percent), hopsage (13 percent), Mojave mixed scrub (10 percent), salt desert scrub (4 percent), sagebrush (3 percent), and pinyon-juniper (much less than 1 percent). None of the more than 210 plant species known to occur in the analyzed land withdrawal area is endemic to the area; that is, they all occur in other places.

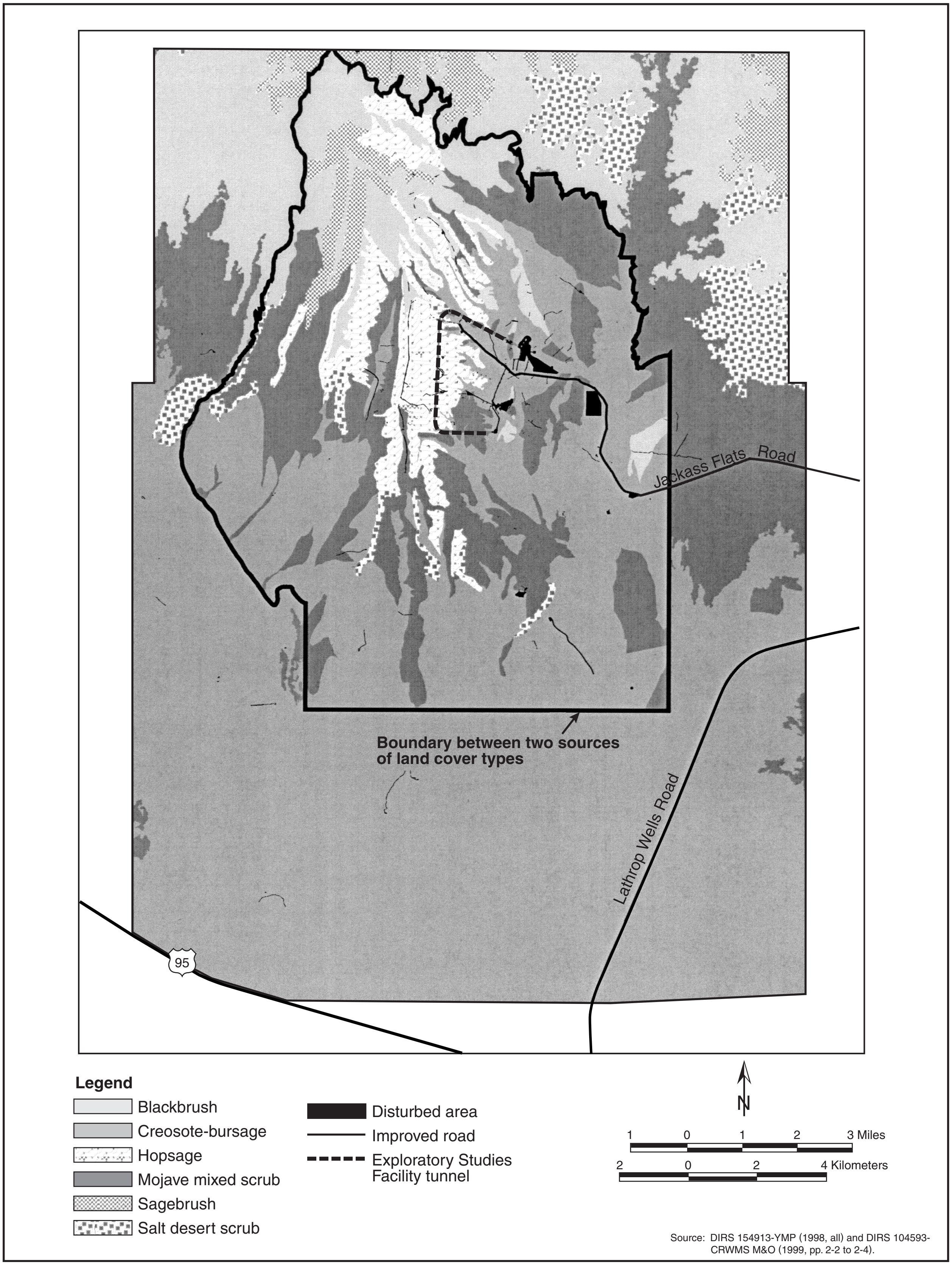


Figure 3-21. Land cover types in the analyzed land withdrawal area.

Plant species typical of the Mojave Desert dominate the vegetation at low elevations in the analyzed land withdrawal area. Low-elevation valleys, alluvial fans, and large washes are dominated by white bursage (*Ambrosia dumosa*), creosotebush (*Larrea tridentata*), Nevada jointfir (*Ephedra nevadensis*), littleleaf ratany (*Krameria erecta*), and pale wolfberry (*Lycium pallidum*). Low-elevation hillsides are dominated by similar species, with the addition of shadscale (*Atriplex confertifolia*), California buckwheat (*Eriogonum fasciculatum*), and spiny hopsage (*Grayia spinosa*).

At higher elevations, generally at the northern end of the analyzed land withdrawal area, species typical of the Great Basin Desert are dominant. Ridge tops and slopes are dominated by blackbrush (*Coleogyne ramosissima*), heathgoldenrod (*Ericameria teretifolius*), Nevada jointfir, broom snakeweed (*Gutierrezia sarothrae*), green ephedra (*Ephedra viridis*), and California buckwheat. On some steep north-facing slopes, big sagebrush (*Artemisia tridentata*) is predominant.

There are approximately 30 exotic plant species present in the Yucca Mountain area. The most common species include red brome (*Bromus rubens*), Russian thistle (*Salsola* spp.), tumble mustard (*Sisymbrium altissimum*), halogeton (*Halogeton glomeratus*), and Arabian schismus (*Schismis arabicus*). Red brome is the most abundant exotic species in the area. None of these exotic species is on the State of Nevada's Noxious Weed List (DIRS 155925-NWAC 2000, Appendix A).

3.1.5.1.2 *Wildlife*

Wildlife at Yucca Mountain is dominated by species associated with the Mojave Desert, with some species from the Great Basin Desert at higher elevations.

The 36 species of mammals that have been observed in the analyzed Yucca Mountain land withdrawal area include 17 species of rodents, seven species of bats, three species of rabbits and hares, and nine species of large mammals such as coyote *(Canis latrans)*, mule deer *(Odocoileus hemionus)*, and burros (*Equus asinus*). The most abundant species are long-tailed pocket mice *(Chaetodipus formosus*) and Merriam's kangaroo rats (*Dipodomys merriami*).

The 27 species of reptiles include 12 species of lizards, 14 species of snakes, and the desert tortoise (*Gopherus agassizii*). The most abundant lizard is the side-blotched lizard (*Uta stansburiana*), while the western whiptail (*Cnemidophorus tigris*) is common. The most abundant snakes are the coachwhip (*Masticophis flagellum*) and the long-nosed snake (*Rhinocheilus lecontei*). No amphibians have been found at Yucca Mountain.

There have been no formal attempts to quantify the birds present at Yucca Mountain, but at least 120 species have been sighted in or near the analyzed land withdrawal area, including 14 species that nest there. Transient and resident species have been recorded including species typical of the desert, migrating water birds and warblers, and raptors. Black-throated sparrows (*Amphispiza bilineata*) are the most common resident birds and mourning doves (*Zenaida macroura*) are seasonally common.

Researchers have collected invertebrates from 18 orders and 53 families at Yucca Mountain. Members of the insect orders Lepidoptera (butterflies and moths), Hymenoptera (bees, wasps, and ants), and Coleoptera (beetles) were the most numerous of those collected.

Several game species and furbearers (see Nevada Administrative Code 503.125) have been observed in the analyzed land withdrawal area, including (1) three species of game birds—Gambel's quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), and mourning doves, (2) mule deer (*Odocoileus hemionus*), and (3) three species of furbearers—kit foxes (*Vulpes velox*), mountain lions (*Puma concolor*), and bobcats (*Lynx rufus*).

3.1.5.1.3 *Special Status Species*

No plant species listed as threatened or endangered or that are proposed or candidates for listing under the Endangered Species Act occur in the analyzed land withdrawal area. No plant species classified as sensitive by the Bureau of Land Management are known to occur in the analyzed land withdrawal area. Several species of cacti and yucca, all of which are protected by the State of Nevada from commercial collection, are scattered throughout the region, including the analyzed land withdrawal area.

SPECIAL STATUS SPECIES

An **endangered species** is classified under the Endangered Species Act as being in danger of extinction throughout all or a significant part of its range.

A **threatened species** is classified under the Endangered Species Act as likely to become an endangered species in the foreseeable future.

Candidate species are species for which the Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

The State of Nevada has also designated special status species as endangered, threatened, protected, and sensitive. Species with these classifications are protected under Nevada Administrative Code Chapter 503.

Bureau of Land Management **sensitive species** include species designated by the Bureau's State Director in addition to those listed, proposed, or candidates under the Endangered Species Act or listed by the State of Nevada as endangered or otherwise protected.

One animal species that occurs at Yucca Mountain, the desert tortoise, is listed as threatened under the Endangered Species Act. Yucca Mountain is at the northern edge of the range of the desert tortoise (DIRS 101915-Rautenstrauch, Brown, and Goodwin 1994, p. 11), and the abundance of tortoises at Yucca Mountain is low or very low in comparison to other portions of its range. Aspects of the ecology of the desert tortoise population at Yucca Mountain have been studied extensively (DIRS 104593-CRWMS M&O 1999, all).

Individual bald eagles (*Haliaeetus leucocephalus)* and peregrine falcons (*Falco peregrinus)* occasionally migrate through the region; these species have been seen once each at the Nevada Test Site. Both species are rare in the region and have not been seen at Yucca Mountain. Bald eagles are classified as threatened under the Endangered Species Act, and the State of Nevada classifies both birds as endangered.

No other Federally listed threatened or *endangered species* or candidates for listing under the Endangered Species Act occur at Yucca Mountain.

Five species classified as sensitive by the Bureau of Land Management occur at Yucca Mountain. Two species of bats—the long-legged myotis (*Myotis volans*) and the fringed myotis (*M. thysanodes*)—have been observed near the site. Three other species, the western chuckwalla (*Sauromalus obesus*), burrowing owl (*Speotyto cunicularia*), and Giuliani's dune scarab beetle (*Pseudocotalpa giulianii*), occur in the analyzed land withdrawal area. The chuckwalla, one of the largest lizards in Nevada, is locally common and widely distributed in rocky habitats throughout the analyzed land withdrawal area and the

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surrounding region. The seldom-seen burrowing owl generally occurs in valley bottoms and is known to be a year-round resident at the Nevada Test Site. Giuliani's dune scarab beetle has been found near the cinder cones north of U.S. Highway 95 at the south end of Crater Flat.

Ash Meadows National Wildlife Refuge and Devils Hole (which is administered as part of Death Valley National Park) are about 39 kilometers (24 miles) south of Yucca Mountain. Although Ash Meadows and Devils Hole are outside the region of influence for biological resources, they contain a number of special status species that an evaluation of regional biological resources should consider. Of the eight endemic plant species at Ash Meadows, one is listed as endangered (Amargosa alkali plant, *Nitrophila mohavensis*) and six are listed as threatened (Spring-loving centaury, *Centaurium namophilum*; Ash Meadows milkvetch, *Astragalus phoenix*; Ash Meadows naked stem sunray, *Enceliopsis nudicaulis* var. *corrugata*; Kings Mousetail, *Ivesia kingii* var. *eremica*; Ash Meadows gumweed, *Grindelia fraximopratensis*; and Ash Meadows blazing star, *Mentzelia leucophylla*) (50 *FR* 20777, May 20, 1985). Four endemic fish species occur in the springs and pools. The Fish and Wildlife Service and the State of Nevada list these species—the Ash Meadows Amargosa speckled dace (*Rhinichthys osculus nevadensis*), Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*), Devils Hole pupfish (*C. diabolis*), and Warm Springs Amargosa pupfish (*C. nevadensis pectoralis*)—as endangered. The springs also provide habitat for a number of endemic riffle beetles, springsnails, and other invertebrates, including the threatened Ash Meadows naucorid bug (*Ambrysus amargosus*).

3.1.5.1.4 *Wetlands*

There are no naturally occurring jurisdictional wetlands (wetlands that are regulated under Section 404 of the Clean Water Act) at Yucca Mountain. Four manmade ponds in the Yucca Mountain region have *riparian* vegetation. Fortymile Wash and some of its tributaries might be classified as waters of the United States as defined by the Clean Water Act. Jurisdictional wetlands associated with Ash Meadows are outside the region of influence for the Proposed Action.

3.1.5.2 Soils

Researchers have conducted a soil survey centered on Midway Valley (the location of the proposed North Portal facilities) and the ridges to the west (DIRS 103450-Resource Concepts 1989, all), and a more general soil survey of the entire Yucca Mountain region (DIRS 104851-YMP 1997, all). The survey that centered on Midway Valley identified 17 soil series and seven map units (Table 3-20) at Yucca Mountain (DIRS 103450-Resource Concepts 1989, all); none of these series is classified as *prime farmland*. Based on a wetlands assessment at the Nevada Test Site (DIRS 101833-Hansen et al. 1997, all), there are no hydric soils at Yucca Mountain. Yucca Mountain soils are derived from underlying volcanic rocks and mixed alluvium dominated by volcanic material, and in general have low water-holding capacities.

SOIL TERMS

Prime farmland: Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not included). It has the soil quality, growing season, and moisture supply needed for the economic production of sustained high yields of crops when treated and managed (including water management) according to acceptable farming methods (Farmland Protection Policy Act of 1981, 7 CFR 7.658).

Piedmont: Land lying along or near the foot of a mountain. For example, a fan piedmont is a fan-shaped landform between the mountain and the basin floor.

The shallow soils on ridge tops at Yucca Mountain often consist of a thin *hardpan* (hardened or cemented soil layer) on top of bedrock and range from *well drained* to

Table 3-20. Soil mapping units at Yucca Mountain.[a]

Map unit	Percent	Geographic setting	Soil characteristics
Upspring-Zalda	11	Mountain tops and ridges. Soils occur on smooth, gently sloping ridge tops and shoulders and on nearly flat mesa tops. Rhyolite and tuffs are parent materials for both soil types.	Typically shallow (10 - 51 cm[b]) to bedrock, or to thin duripan[c] over bedrock. They are well to excessively drained, have low available water-holding capacity, medium to rapid runoff potential, and slight erosion hazard.
Gabbvally-Downeyville-Talus	8	North-facing mountain sideslopes. Talus is stone-sized rock occurring randomly throughout unit in long, narrow, vertically oriented accumulations.	Shallow (10 - 36 cm) to bedrock. Permeability is moderate to moderately rapid. They have moderate to rapid runoff potential, are well drained, and have low available water-holding capacity and moderate erosion hazard.
Upspring-Zalda-Longjim	27	Mountain sideslopes. Soils occur on south-, east-, and west-facing slopes, and on moderately sloping alluvial deposits below sideslopes.	Shallow (10 - 51 cm) to bedrock or to thin duripan over bedrock. They are well to excessively drained and have moderately rapid to rapid permeability and runoff potential, very low available water-holding capacity, and slight erosion hazard.
Skelon-Aymate	22	Alluvial fan remnants. Soils occur on gently to strongly sloping summits and upper sideslopes.	Moderately deep (51 - 102 cm) to indurated[d] duripan or petrocalcic[e] layer with low to very low available water-holding capacity, moderately rapid permeability, slow runoff potential, and slight erosion hazard.
Strozi variant-Yermo-Bullfor	7	Alluvial fan remnants. Soils occur on gently to moderately sloping alluvial fan remnants and stream terraces adjacent to large drainages.	Moderately deep (51 - 102 cm) to deep (102 cm). They are well drained and have rapid permeability, very low available water-holding capacity, slow runoff potential, and slight erosion hazard.
Jonnic variant-Strozi-Arizo	12	Dissected alluvial fan remnants. Soils occur on fan summits, moderately sloping fan sideslopes, and inset fans. They are formed in alluvium from mixed volcanic sources.	Moderately deep (36 - 43 cm) to deep (more than 102 cm), sometimes over strongly cemented duripan. They have slow or rapid permeability, slow or moderate runoff potential, very low available water-holding capacity, and slight erosion hazard.
Yermo-Arizo-Pinez	13	Inset fans and low alluvial sideslopes in mountain canyons; and drainages between fan remnants. Soils occur on moderately to strongly sloping inset fans near drainages, adjacent to lower fan remnants, and below foothills.	Deep (more than 102 cm), sometimes over indurated duripan. They are well drained and have very low available water holding-capacity, moderately slow to rapid permeability, slow to medium runoff potential, and slight erosion hazard.

a. Source: DIRS 104592-CRWMS M&O (1999, pp. 3 and 4).
b. To convert centimeters (cm) to inches, multiply by 0.3937.
c. Duripan: A subsurface layer cemented by silica, usually containing other accessory cements.
d. Indurated: Hardened, as in a subsurface layer that has become hardened.
e. Petrocalcic: A subsurface layer in which calcium carbonate or other carbonates have accumulated to the extent that the layer is cemented or indurated.

excessively drained, which means that water drains readily to very rapidly. The soil has a topsoil layer typically less than 15 centimeters (6 inches) thick and, in some instances, a subsoil layer 5 to 30 centimeters (2 to 12 inches) thick. Soil textures range from gravelly to cobbly, loamy sands to sandy loams. Soils are calcareous (high in calcium carbonate), with lime coatings on the undersides of rocks in the subsoil layer. The soils are moderately to strongly alkaline, with a *pH* ranging from 8.0 to 8.6. Rock fragments ranging in size from gravel to cobbles dominate 45 to 65 percent of the ground surface.

Soils on fan piedmonts and in steep, narrow canyons are relatively deep and are *well drained* (water is drained readily, but not rapidly). These soils developed from residues of volcanic parent material, with a component of calcareous eolian sand. Soils formed from the volcanic parent material generally range from *moderately shallow* [50 to 75 centimeters (20 to 30 inches)] to *moderately deep* [75 to 100 centimeters (30 to 40 inches)] over a thin hardpan on top of bedrock. The topsoil layers are generally less than 25 centimeters (10 inches) thick, with a subsoil layer thickness of 25 to 50 centimeters (10 to 20 inches). The mixed soils, containing residues from volcanic parent material and calcareous eolian sand, are often *deep* [100 to 150 centimeters (40 to 60 inches)] or moderately deep, having a well-cemented hardpan. The topsoil layers are less than 15 centimeters (6 inches) thick, with the layer of soil parent material as deep as 150 centimeters (60 inches). Soil textures are gravelly, sandy loams with 35 to 70 percent rock fragments. Soils are generally calcareous and moderately to strongly alkaline.

Soils on alluvial fans and in stream channels are *very deep* [greater than 150 centimeters (60 inches)] and range from well drained to excessively drained. The topsoil layers are generally less than 20 centimeters (8 inches) thick, with the layer of soil parent material as deep as 150 centimeters. Soil textures are very gravelly, with fine sands to sandy loams and abundant rock fragments. The soils are calcareous and moderately alkaline.

The Yucca Mountain site characterization project has sampled and analyzed surface soils for radiological constituents. In addition, records of spills or releases of nonradioactive materials have been maintained to meet regulatory requirements and to provide a baseline for the Proposed Action. A recent summary of existing radiological conditions in soils is based on 98 surface samples collected within 16 kilometers (10 miles) of the Exploratory Studies Facility. The results of that analysis, when compared to other parts of the world, indicate average levels of the naturally occurring radionuclide uranium-238 series decay products and above-average levels of the naturally occurring radionuclides potassium-40 and thorium-232 series decay products. The higher-than-average radionuclide values might be due to the origin of the soil at the site from tuffaceous igneous rocks. The studies also detected concentrations of the manmade radionuclides strontium-90, cesium-137, and plutonium-239 from worldwide nuclear weapons testing.

3.1.6 CULTURAL RESOURCES

Cultural resources include any prehistoric or historic district, site, building, structure, or object resulting from or modified by human activity. Cultural resources could also include potential *traditional cultural properties*. Under Federal regulation, cultural resources designated as historic properties warrant consideration with regard to potential adverse impacts resulting from proposed Federal actions. A cultural resource is an historic property if its attributes make it eligible for listing or it is formally listed on the *National Register of Historic Places*. For this analysis, DOE has

CULTURAL RESOURCES

Archaeological site: The location of a past event, a prehistoric or historic occupation or activity, or a building or structure, whether standing, ruined, or vanished, where the location itself maintains archaeological value.

Traditional cultural property: A property associated with the cultural practices or beliefs of a living community that are (1) rooted in that community's history, and (2) important in maintaining the cultural identity of the community.

evaluated the importance of historic and archaeological resources according to National Register eligibility criteria.

Cultural resources at Yucca Mountain include archaeological resources that are prehistoric or historic, and other resources important to Native American tribes and organizations, such as potential traditional cultural properties. The region of influence for cultural resources includes the land areas that would be disturbed by the proposed repository activities (as described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur. DOE has collected information on the various types of archaeological sites, detailing their purposes and the kinds of artifacts typically present. DOE also has focused on Native American interests in the region's cultural resources. Section 3.1.6.2 summarizes these issues in discussions of Native American views of the affected environment.

Unless otherwise indicated, the information in this section is derived from either the summary of past archaeological projects at Yucca Mountain (DIRS 104997-CRWMS M&O 1999, all) or from *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all).

3.1.6.1 Archaeological and Historic Resources

Site characterization efforts have led to a number of archaeological investigations at Yucca Mountain over the past two decades, including, as an early action, an archaeological field survey of a 44-square-kilometer (about 11,000-acre) parcel that proposed repository activities probably would affect. The field survey was followed by limited test excavations at 29 sites to determine their scientific importance and to develop management strategies for the protection of archaeological resources. Additional archaeological surveys have been conducted along nearby Midway Valley and Yucca Wash, in lower Fortymile Canyon just east of the Yucca Mountain site, and around Dune Wash east of southern Yucca Mountain.

Concurrent with these investigations, DOE directed archaeological surveys and data-recovery projects before beginning planned ground-disturbing activities specific to the Yucca Mountain Project. Limited data-recovery efforts at 18 archaeological sites support a model for a local cultural sequence that includes a pattern of linear-shaped sites along major drainages dating as far back as 7,000 years, and a shift to a more dispersed pattern of sites about 1,500 years ago. A site monitoring program designed to examine human and natural impacts to cultural resources through time began in 1991 and is continuing at Yucca Mountain.

Decades of cultural resource investigations at Yucca Mountain and at the Nevada Test Site have revealed archaeological features and artifacts. Based on archaeological site file searches at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, approximately 830 archaeological sites have been discovered in the analyzed land withdrawal area. Most of the known archaeological sites are small scatters of lithic (stone) artifacts, usually comprised of fewer than 50 artifacts with few formal tools and no temporally or culturally diagnostic artifacts in the inventory. None of the sites has been listed on the *National Register of Historic Places*, but 150 are considered by DOE to be eligible for nomination as historic properties (see Table 3-21) based on National Register eligibility criteria. Several reports describe the specific procedures used to study and protect these cultural sites (DIRS 104807-CRWMS M&O 1995, all; DIRS 104810-CRWMS M&O 1995, all; DIRS 104813-CRWMS M&O 1995, all; DIRS 104814-CRWMS M&O 1995, all; DIRS 104818-CRWMS M&O 1995, all; DIRS 104819-CRWMS M&O 1995, all; DIRS 104822-CRWMS M&O 1995, all; DIRS 104824-CRWMS M&O 1995, all; DIRS 103198-YMP 1992, all). DIRS 104558-DOE (1988, all) describes how the Department meets its responsibilities under Section 106 of the National Historic Preservation Act and the American Indian Religious Freedom Act, and interactions with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer.

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Table 3-21. Sites in the analyzed land withdrawal area potentially eligible for the *National Register of Historic Places.*

Type	Number
Temporary camps	43
Extractive localities	14
Processing localities	9
Localities	77
Caches	2
Stations	1
Historic sites	4
Total	***150***

This EIS separates archaeological sites into two broad groups, prehistoric and historic, separated by the first contact between American Indians and Euroamericans; in the Great Basin, this contact occurred in the early 1800s. The oldest prehistoric sites in southern Nevada are about 11,000 years old. These sites include one or more of the following features: temporary campsites, rock art, scattered lithic artifacts, quarries, plant-processing remains, hunting blinds, and rock alignments. The sites are categorized as temporary camps, extractive localities, processing localities, localities, caches, and stations. Historic sites include mining sites, ranching sites, transportation and communication sites, and some Cold War facilities. The following paragraphs define eligible types of sites at Yucca Mountain in each group (Table 3-21).

Temporary Camps. When occupied by a group of people, a temporary camp was a hub of activity for raw materials processing, implement manufacturing, and maintenance and general living activities. Camp artifacts typically include debris and discards from the making of stone tools, projectile points, bifacial stone tools, cores, milling stones, pottery, specialized tools, hearths, shelters, structures, and art. The nature and diversity of artifacts and features are the basis for designating a site as a temporary camp.

Extractive Localities. These were sites for specific extractive or resource-procurement tasks. They probably were occupied for short periods and for such limited activities as toolstone quarrying, hunting, and seed gathering. A single locality can contain isolated artifacts or large quantities of artifacts that reflect specific activities. In comparison to temporary camps, extractive localities have a low diversity of artifacts. Extractive locality artifacts include isolated projectile points or bifacial stone tools where hunting occurred, toolstone quarries with thousands of flakes, diffuse scatters of lithic flakes where plant materials were gathered, hunting blinds, and *tinajas* or water-catchment basins.

Processing Localities. Specific resource-processing tasks occurred at processing localities. These localities probably were occupied only for short periods and for limited activities such as butchering, milling, and roasting. A single site can contain an isolated artifact or large quantities of artifacts that reflect specific activities. Like extractive localities, processing localities have a low diversity of artifacts. Examples of processing localities include stone tool manufacturing stations, milling stations for processing food, diffuse scatters containing stone tools for processing meat and hides, hearths, and roasting pits.

Localities. This category includes sites that might have been either extractive or processing localities but for which there is not enough information to determine if such activities occurred.

Caches. Caches are temporary places for storing resources or artifacts. They include sealed rock shelters, rock piles, rock rings without evidence of habitation, rock alignments, brush piles held in place by rocks, and storage pits. A cache can also be an association of similar artifacts such as heat-treated bifacial stone tools, projectile points, and snares, or such resources as toolstone blanks and firewood in or on a natural feature such as at the base of a tree, in a rock shelter, or in a mountain saddle. Caches are distinguished from localities as places for storing resources, rather than as places of procurement or processing.

Stations. Stations are sites where groups gathered to exchange information about such things as game movement, routes of travel, and ritual activities. Examples of stations are rock cairns marking routes of travel, isolated petroglyphs and pictographs, geoglyphs, and observation points and overlooks.

Historic Sites. Historic sites are contemporaneous with or postdate the introduction of European influences in the region. Historic archaeological sites are few in number in the project area, usually represented by a small scatter of artifacts (cans and bottles). These short-term activities were related to mining, ranching, and transportation.

3.1.6.2 Native American Interests

3.1.6.2.1 *Yucca Mountain Project Native American Interaction Program*

In 1987, DOE initiated the Native American Interaction Program to consult and interact with tribes and organizations on the characterization of the Yucca Mountain site and the possible construction and operation of a repository. These tribes and organizations—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone people from Arizona, California, Nevada, and Utah—have cultural and historic ties to the Yucca Mountain area.

The Native American Interaction Program concentrates on the protection of cultural resources at Yucca Mountain and promotes a government-to-government relationship with the tribes and organizations. Its purpose is to help DOE comply with various Federal laws and regulations, including the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the National Historic Preservation Act, the Native American Graves Protection and Repatriation Act, DOE Order 1230.2 (*American Indian and Tribal Government Policy*), and Executive Orders 13007 (*Indian Sacred Sites*) and 13084 (*Consultation and Coordination with Indian Tribal Governments*). These regulations mandate the protection of archaeological sites and cultural items and require agencies to include Native Americans and Federally recognized tribes in discussions and interactions on major Federal actions.

Initial studies identified three tribal groups—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone—whose cultural heritage includes the Yucca Mountain region (DIRS 104927-Stoffle 1987, p. 5-13). Additional ethnographic efforts eventually identified 17 tribes and organizations involved in the Yucca Mountain Project Native American and cultural resource studies. Figure 3-22 shows the traditional boundaries and locations of the 17 tribes and organizations.

Of the 17 tribal groups, 15 are Federally recognized tribes. The Pahrump Paiute Indian Tribe, which consists of a group of Southern Paiutes living in Pahrump, Nevada, has applied for Federal tribal recognition but to date has not received it. In addition, the Las Vegas Indian Center is not a Federally recognized tribe, but DOE included it in the Native American Interaction Program because it represents the urban Native American population of Las Vegas and Clark County, Nevada (DIRS 103465-Stoffle et al. 1990, p. 7).

The 17 tribes and organizations have formed the Consolidated Group of Tribes and Organizations, which consists of officially appointed tribal representatives who are responsible for presenting their respective tribal concerns and perspectives to DOE. The primary focus of this group has been the protection of cultural resources and environmental restoration at Yucca Mountain. Members of the group have participated in many ethnographic interviews and have provided DOE valuable insights into Native American cultural and religious values and beliefs. These interactions have produced several reports that record the regional history of Native American people and the interpretation of Native American cultural resources in the Yucca Mountain region (DIRS 104958-DOE 1989, pp. 30 to 74; DIRS 103465-Stoffle et al. 1990, pp. 11 to 25; DIRS 104959-DOE 1990, pp. 23 to 49). In addition, tribal representatives have identified and discussed traditional and current uses of plants in the area (DIRS 103464-DOE 1989, pp. 22 to 139).

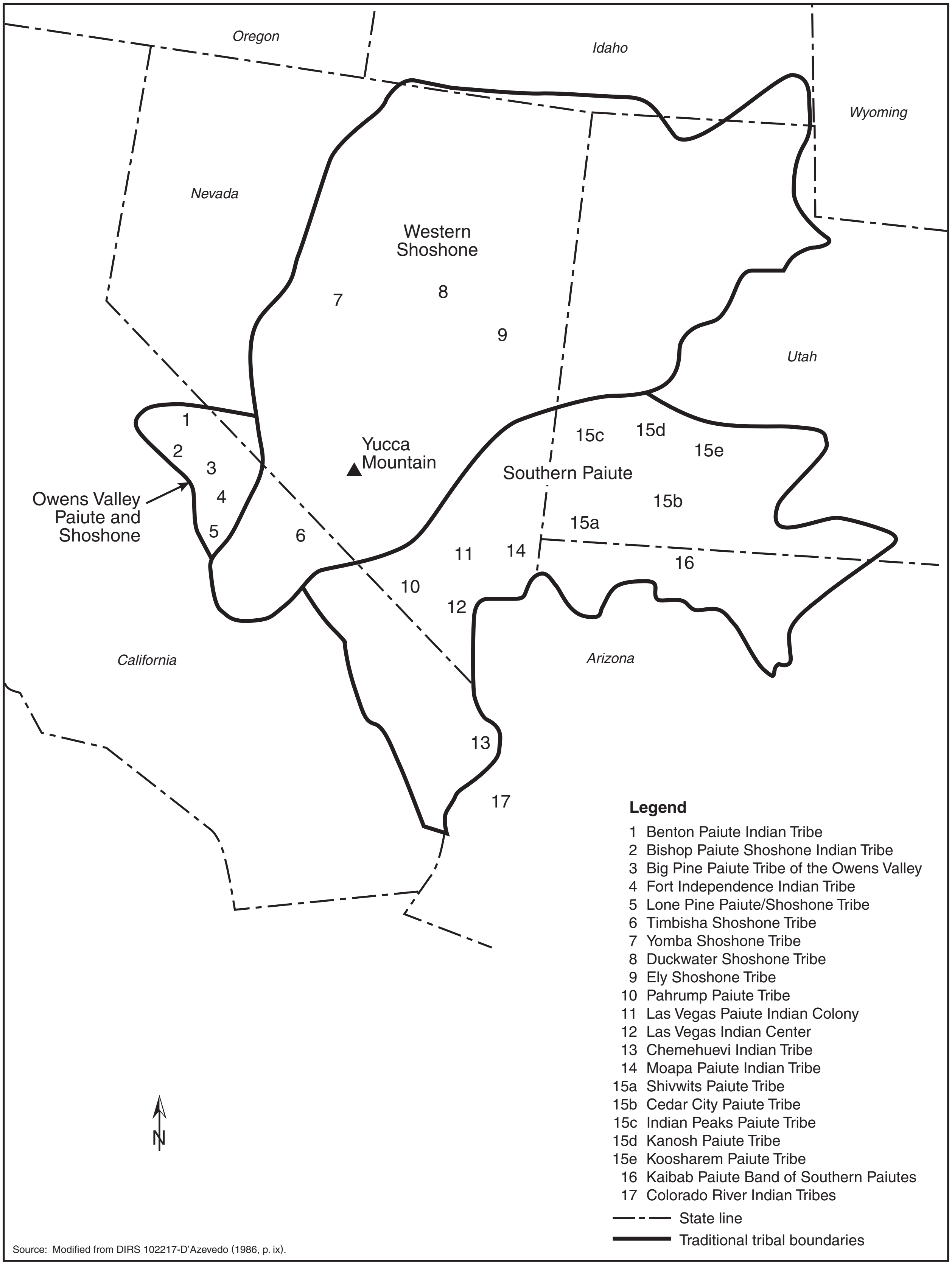

Figure 3-22. Traditional boundaries and locations of tribes in the Yucca Mountain region.

3.1.6.2.2 *Native American Views of Affected Environment*

During the EIS scoping process, DOE visited many tribes to encourage their participation. Members of the Consolidated Group of Tribes and Organizations designated individuals who represented the three tribal entities (Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone) to document their viewpoints on the Yucca Mountain area. This group, the American Indian Writers Subgroup, prepared a resource document that provides Native American perspectives on the repository (DIRS 102043-AIWS 1998, all). This report also describes the relationship between Native American people and DOE and discusses impacts of the Proposed Action while recommending impact mitigation approaches for reducing potential impacts to Native American resources and other heritage values in the Yucca Mountain region. In addition to the general and specific cultural resources issues, which are summarized in the following paragraphs, the report covers other critical topics, including concerns for occupational and public health and safety, environmental justice and equity issues, and social and economic issues. The report also provides recommendations for the conduct of appropriate consultation procedures for the repository and associated activities, and requests Native American participation in development of project resource management approaches to enable the incorporation of accumulated centuries of ethnic knowledge in long-term cultural resource protection strategies.

Native Americans believe that they have inhabited their traditional homelands since the beginning of time. Archaeological surveys have found evidence that Native Americans used the immediate vicinity of Yucca Mountain on a temporary or seasonal basis (DIRS 103465-Stoffle et al. 1990, p. 29). Native Americans emphasize that a lack of abundant artifacts and archaeological remains does not mean that their people did not use a site or that the land is not an integral part of their cultural ecosystem. Native Americans assign meanings to places involved with their creation as a people, religious stories, burials, and important secular events. The traditional stories of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples identify such places, including the Yucca Mountain area.

Native Americans believe that cultural resources are not limited to the remains of native ancestors but include all natural resources and geologic formations in the region, such as plants and animals and natural landforms that mark important locations for keeping their historic memory alive and for teaching their children about their culture. Equally important are the water resources and minerals in the Yucca Mountain region. Native Americans used traditional quarry sites to make tools, stone artifacts, and ceremonial objects; many of these sites are *power places* associated with traditional healing ceremonies. Despite the current physical separation of tribes from Yucca Mountain and neighboring lands, Native Americans continue to value and recognize the meaningful role of these lands in their culture and continued survival. Many areas in the Yucca Mountain region are important to them. Fortymile Canyon was an important crossroad where a number of traditional trails from such distant places as Owens Valley, Death Valley, and the Avawtz Mountain came together. Oasis Valley was an important area for trade and ceremonies. Native Americans believe that Prow Pass was an important ceremonial site and, because of this religious importance, have recommended that DOE conduct no studies in this area. Other areas are important based on the abundance of artifacts, traditional-use plants and animals, rock art, and possible burial sites.

According to Native Americans, the Yucca Mountain area is part of the holy lands of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples. Native Americans generally do not concur with the conclusions of archaeological investigators that their ancestors were highly mobile groups of aboriginal hunter-gatherers who occupied the Yucca Mountain area before Euroamericans began using the area for prospecting, surveying, and ranching. They believe that these conclusions overlook traditional accounts of farming that occurred before European contact. Yucca Mountain and nearby lands were central in the lives of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples, who shared them for religious ceremonies, resource uses, and social events. Native Americans value the cultural resources in these areas, viewing them in a holistic manner. They believe that the water, animals, plants, air, geology, and artifacts are interrelated and dependent on each other for existence.

3.1.7 SOCIOECONOMICS

To define the existing conditions for the socioeconomic environment in the Yucca Mountain region, DOE determined the current economic and demographic status in a well-defined region (called the *region of influence*) near the site of the proposed repository. DOE based its definition of the socioeconomic region of influence on the distribution of the residences of current employees of the Department and its contractors who work on the Yucca Mountain Project or at the Nevada Test Site. The region of influence, therefore, consists of the three Nevada counties (Clark, Lincoln, and Nye Counties) where about 98 percent of the DOE 2001 workforce lives. The region of influence includes Lincoln County because of the possibility that DOE could build and operate an intermodal transfer station there. The Department used the residential distribution, which reflects existing commuting patterns, to estimate the future distribution of direct workers associated with the Proposed Action and the No-Action Alternative.

The socioeconomic region of influence for the Proposed Action, consisting of Clark, Lincoln, and Nye Counties in Southern Nevada, is shown in Figure 3-23. Clark County contains the City of Las Vegas and its suburbs. Based on a count of workers in a 1994 data report, 79 percent of the Yucca Mountain Project and Nevada Test Site onsite employees live in Clark County and approximately 19 percent live in Nye County (Table 3-22).

Table 3-22. Distribution of Yucca Mountain Project and Nevada Test Site employees by place of residence.[a]

Place of residence	Onsite workers	Percent of total
Clark County	1,268	79
Lincoln County	5	<1
Nye County	308	19
Total region of influence[b]	1,581	98
Outside region of influence	31	2
Total respondents[b]	***1,612***	***100.0***

a. Source: DIRS 104957-DOE (1994, Table 2-7).
b. Subtotals may not add to totals because of rounding.

DOE received numerous reports from affected units of local government providing socioeconomic baseline environmental information. In addition, DOE regularly requests and receives economic and demographic data from local and State of Nevada agencies. The data and reports contain information that characterizes the existing community environment, provides assessments of economic development, or includes basic economic and demographic trends. DOE reviewed these reports and incorporated pertinent information in this EIS.

DOE used the REMI Economic-Demographic Forecasting System model to estimate the baseline for population, employment, and three other economic measures: Gross Regional Product, real disposable income, and State and local government spending. The baseline was projected from 2000 to 2035 for the three counties in the Region of Influence, for the Rest of Nevada, and for all of Nevada. This baseline information is provided in Table 3-23. The REMI model was used to estimate changes to the socioeconomic measures from the baseline based on different cases for repository construction and operation and for different transportation options. These changes from the baseline are discussed in Chapters 4 and 6.

The version of the REMI model used for the Final EIS is based on historical data through 1997. This model was updated to include State of Nevada employment data for 1998. Additional local information was incorporated in the baseline projections. These included expected near-term changes and long-term stability in the mining industry in Nye County; changes in employment by DOE during 1999 and 2000; and expected increases in hotel-casino employment as a result of openings of new hotels and casinos through 2001. Finally, the baselines were adjusted to account for population estimates and projections made for Clark and Nye Counties and by the Nevada State Demographer's Office.

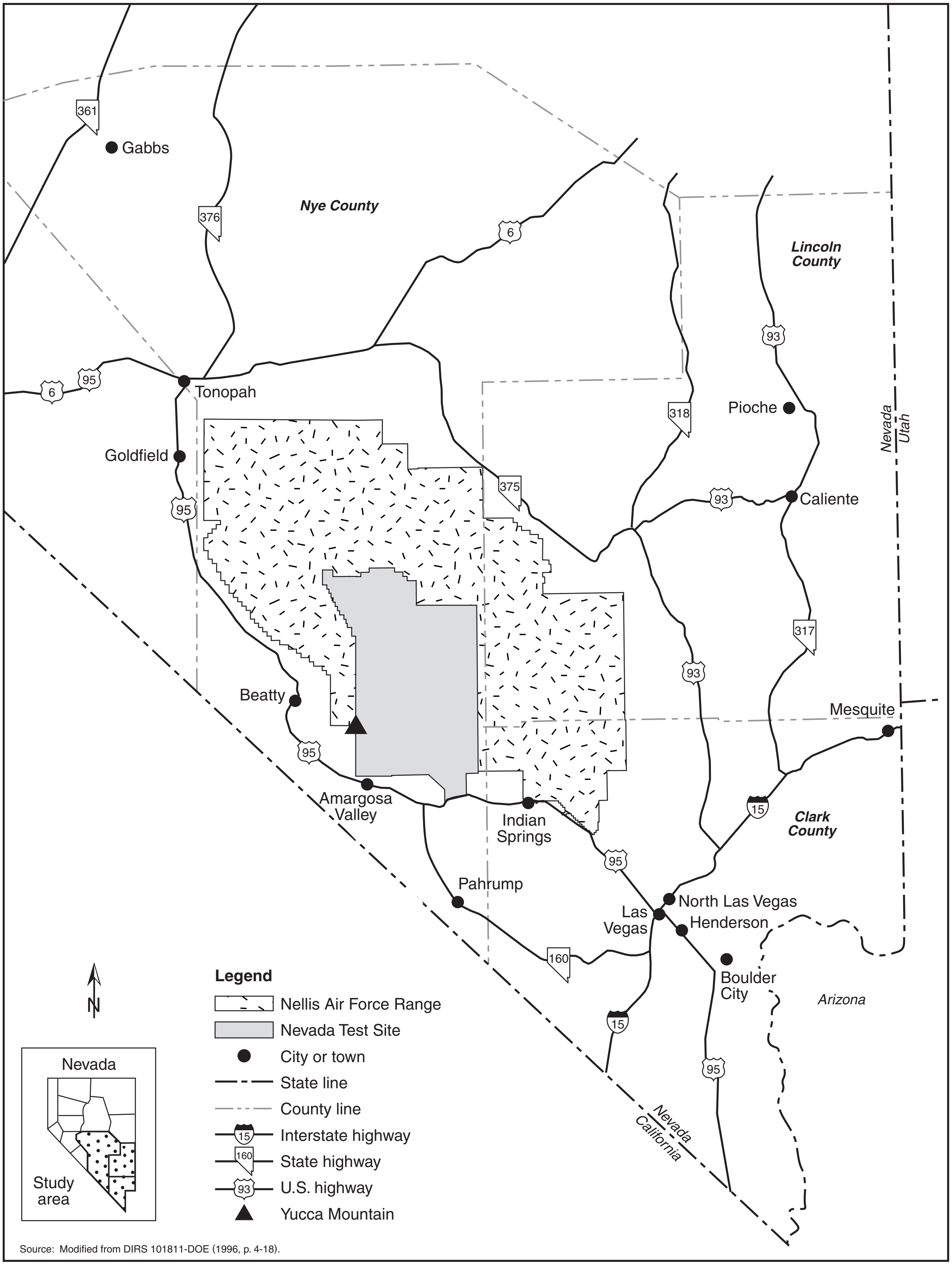

Figure 3-23. Socioeconomic region of influence.

Table 3-23. Baseline values for population, employment, and economic variables, 2000 to 2035.

Economic parameter	2000	2005	2010	2015	2020	2025	2030	2035
Population[a]								
Clark County	1,383,113	1,633,935	1,836,548	2,017,067	2,174,210	2,327,484	2,492,956	2,668,860
Nye County	40,656	49,387	56,759	62,641	67,351	72,047	76,952	82,417
Lincoln County	4,389	4,421	4,405	4,521	4,644	4,824	5,027	5,281
Rest of Nevada	598,047	645,720	690,171	753,120	814,231	872,195	929,565	992,999
All of Nevada	2,026,205	2,333,463	2,587,883	2,837,349	3,060,436	3,276,550	3,504,500	3,749,557
Employment[a]								
Clark County	830,265	909,842	980,618	1,045,289	1,099,697	1,151,187	1,211,596	1,283,384
Nye County	12,883	14,665	16,324	17,437	18,205	18,917	19,812	20,968
Lincoln County	2,249	2,419	2,527	2,612	2,664	2,732	2,835	2,987
Rest of Nevada	384,756	416,109	438,589	460,244	478,861	497,120	519,138	547,305
All of Nevada	1,230,153	1,343,035	1,438,058	1,525,582	1,599,427	1,669,956	1,753,381	1,854,644
Gross Regional Product[a,b,c]								
Clark County	45.3	50.2	55.7	61.1	66.1	71.3	77.5	84.7
Nye County	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3
Lincoln County	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Rest of Nevada	20.9	23.7	26.2	28.6	31.0	33.4	36.1	39.4
All of Nevada	66.9	74.9	82.9	90.8	98.3	106.0	114.9	125.6
Government Spending[a,b,c]								
Clark County	4.4	5.4	6.4	7.3	8.1	8.9	9.8	10.8
Nye County	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3
Lincoln County	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rest of Nevada	2.1	3.3	3.7	4.1	4.6	5.0	5.4	6.0
All of Nevada	6.6	8.8	10.2	11.7	12.9	14.1	15.5	17.2
Real Disposable Income[a,b,c]								
Clark County	34.8	37.0	42.7	47.9	52.6	57.4	63.6	71.3
Nye County	0.6	0.8	0.9	1.1	1.2	1.2	1.4	1.5
Lincoln County	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Rest of Nevada	16.5	16.9	18.9	20.9	22.8	24.8	27.3	30.1
All of Nevada	52.0	54.7	62.6	69.9	76.6	83.6	92.3	103.1

a. Values from State Demographer and Local Agencies' Baseline (DIRS 157089-TtNUS 2001, Appendix B, Attachments 5 to 10).
b. 2001 dollars, in billions.
c. Sums may not add to totals because of rounding.

Chapter 3 cites information, when available, from the 2000 Census as gathered by the Bureau of the Census. The analysis of impacts to socioeconomic parameters, including population and employment, in subsequent chapters are projected, however, from baselines developed with input from the State of Nevada and local sources.

Section 3.1.7.2 discusses employment estimates by industrial sectors by county in the region of influence.

3.1.7.1 Population

Southern Nevada has been and continues to be among the fastest-growing areas in the country. During the 1980s, the population of the region of influence had an average annual growth rate of 4.8 percent, with a total growth of 66.5-percent for the decade, adding more than 29,000 people annually and reaching 780,000 residents in 1990. In comparison to the State of Nevada, which had a growth of 50.1 percent between 1980 and 1990, the United States had a growth of less than 10 percent during the same period (DIRS 102119-Bureau of the Census 1995, all). This trend has continued during the 1990s. By 2000, the population of Clark County was about 1.4 million people. The region of influence grew by 88 percent from 1990 to 2000, averaging almost 65,000 new residents annually. In 2000, the estimated population

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2000 CENSUS DATA AND UPDATED REMI MODEL

After issuing the Draft EIS and reviewing public comments on that document, DOE began revisiting its socioeconomic baseline projections and estimated impacts for the Final EIS utilizing data available from the State of Nevada and local communities. The revisions included an estimated baseline projection to 2035 for the socioeconomic parameters considered in the EIS.

In March 2001, while the preparation process for this Final EIS was under way, the Bureau of the Census released its county-level population data for Nevada based on its 2000 Census. In addition, DOE received a newly updated REMI model, with historical data through 1998. DOE then prepared an additional baseline projection, using the updated REMI model, for the Region of Influence, the Rest of Nevada, and the State of Nevada. This additional baseline incorporated State employment data for 1999, DOE employment for Nevada in 2000, expected additional hotel-casino employment due to an increase in the number of hotel rooms, expected near-term changes and long-term stability in the mining industry in Nye County, and population estimates and projections made for Clark and Nye Counties and by the Nevada State Demographer's Office. The data was adjusted such that 2000 populations match the Decennial Census estimates. The census-anchored baseline was compared to the "local-based" forecast shown in Table 3-23. The census-anchored baseline and the percentage change from the State Demographer and Local Agencies' Baseline forecast for Nevada are listed below:

	Projected 2000 Census-anchored numbers by year, 2000 to 2035							
	2000	2005	2010	2015	2020	2025	2030	2035
Population[a]								
Clark County	1,375,766	1,685,159	1,892,536	2,068,053	2,233,042	2,378,426	2,550,975	2,743,684
Nye County	32,485	41,295	48,407	54,621	60,083	65,516	71,377	77,788
Lincoln County	4,165	4,178	4,192	4,328	4,532	4,717	4,888	5,062
Rest of Nevada	585,842	652,101	706,325	755,923	802,826	852,301	905,780	961,020
All of Nevada	1,998,258	2,382,733	2,651,460	2,882,925	3,090,483	3,300,960	3,533,020	3,787,554
Percent difference[b]	-1.38	2.11	2.46	1.61	0.98	0.74	0.81	1.01
Employment[a]								
Clark County	840,748	922,302	1,000,912	1,080,506	1,147,571	1,197,196	1,253,724	1,337,723
Nye County	13,001	14,947	16,824	18,360	19,592	20,594	21,771	23,465
Lincoln County	2,042	2,195	2,306	2,402	2,471	2,525	2,601	2,728
Rest of Nevada	384,364	412,141	437,244	463,337	483,473	497,075	514,505	543,526
All of Nevada	1,240,154	1,351,585	1,457,286	1,564,605	1,653,107	1,717,390	1,792,601	1,907,442
Percent difference[b]	0.81	0.64	1.34	2.56	3.36	2.84	2.24	2.85

a. Values from 2000 Census-Anchored Baseline (DIRS 157089-TtNUS 2001, Appendix C, Attachments 5 to 10)

b. Percent difference is for the Nevada (total) going from the State Demographer and Local Agencies' Baseline (Table 3-23) to the 2000 Census-Anchored Baseline shown above.

DOE also used the updated REMI model to estimate changes to the baseline for some of the repository design scenarios and transportation options to determine if the use of the revised model would provide meaningfully different estimates of changes in the economic and demographic measures. Sensitivity analyses revealed that the incremental differences between the two were generally small, and that differences in socioeconomic changes for analyzed scenarios and transportation options using the updated model were not meaningful.

DOE elected to base its socioeconomic projections and impact estimates in this Final EIS on the most recently available information from State and local resources, without consideration of the Decennial Census data, in consideration of the critiques received from commenters and for the following reasons:

- Analysis showed that the incremental differences or potential socioeconomic impacts associated with Yucca Mountain Repository activities are basically insensitive to the baseline used or which of the two versions of the model is used.
- The State of Nevada and local communities have not yet made available their independent estimates based on the 2000 Census data.
- There is some uncertainty involving what the final population totals would be for the Census data at the county level.

Similarly, DOE based its estimated population distribution and growth within 80 kilometers (50 miles) of the repository on projections to 2035 using the information from State and local sources. The 80-kilometer population distributions for 2000 and 2035 are shown in Figure 3-25.

of the region of influence was about 1.41 million people. Led by Clark County, Nevada is the fastest growing state in the country. From 1990 to 2000, Nevada had a total growth of 66.3 percent compared to the 13.1-percent overall growth of the United States.

Las Vegas and the immediate surrounding area dominate the Clark County population. The Las Vegas economy is driven by the growth of the hotel, amusement and recreation, and eating and drinking sectors associated with the gaming industry. As the popularity of gaming grew in the 1970s, 1980s, and 1990s, Las Vegas evolved as one of the country's major tourism and convention destinations. In 2000, Las Vegas hosted 35.8 million visitors, contributing $31.5 billion to the local economy (DIRS 148157-LVCVA 1999, all). The tourism trend is expected to continue well into this century. However, there are a number of economic indicators that suggest the growth in the gaming industry is slowing. The relatively moderate housing costs, temperate climate, abundance of recreational opportunities, favorable business conditions, and absence of a State income tax have contributed to commercial and residential growth. The number of retirees (from across the United States) moving to communities in the region of influence is escalating.

Nye County, which has been the site of booms and busts due to fluctuating mining activity and the recent decline of Nevada Test Site employment, is home to approximately 4 percent of the Yucca Mountain Project employees who work in Nevada (DIRS 155987-DOE 2001, Tables 3-14 and 3-22). Pahrump, in southern Nye County, is experiencing growth caused primarily by inmigrating retirees and its proximity to Las Vegas. In 2000, Nye County had about 32,500 residents, having experienced an 82.7-percent growth in the 1990s. The 2000 population in Lincoln County was about 4,200, up from about 3,800 in 1990, a growth of approximately 10.3 percent.

Although the annual growth rate of the region of influence is likely to slow from the extraordinary pace of the 1990s, the population should continue to grow at a rate of 2 to 4 percent a year in this decade. Clark County will continue to lead the population growth in the foreseeable future in the region of influence.

The region of influence includes a number of incorporated cities and towns as well as unincorporated communities (Table 3-24). The largest city in Clark County is Las Vegas, followed by Henderson. In 2000, Las Vegas had a population of about 480,000 compared to Henderson, which had about 180,000 residents. Nye County has no incorporated cities, but the largest community is unincorporated Pahrump, which had an estimated population of about 25,000 in 2000. Lincoln County has only one incorporated city, Caliente, which is the largest community with a 2000 population of about 1,100.

Clark County has a population density of about 140 persons per square mile. Lincoln County has approximately 0.4 person per square mile, and Nye County has a population density of about 1.4 persons per square mile.

Population growth in the State of Nevada and Clark County is expected to exceed average national trends through 2035. The explosive population growth in Clark County is expected to slow, but remain well above national averages, at about 3 percent through 2035. Clark County will continue to house approximately 97 percent of the population in the region of influence. Nye County is also expected to grow at an accelerated rate, with an average annual increase of approximately 2 percent to 2035. Lincoln County is expected to experience less than 1-percent annual growth through the first third of this century. Figure 3-24 shows estimated populations for the region of influence and the State of Nevada, projected out to 2035.

3.1.7.2 Employment

Of the three counties that comprise the region of influence, Clark County has by far the largest economy; in 2000, the estimated employment was about 840,000. This constituted 98 percent of the regional

Table 3-24. Population of incorporated cities and selected unincorporated towns, 1991 to 2000.[a]

Jurisdiction	1991[b]	1995[b]	2000[c]
Clark County			
Boulder City	13,000	14,000	15,000
Henderson	77,000	120,000	180,000
Indian Springs[d]	N/A[e]	N/A	1,300
Las Vegas	290,000	370,000	480,000
Mesquite	2,100	5,100	9,400
North Las Vegas	51,000	78,000	120,000
Nye County			
Amargosa Valley[d]	920	1,200	1,200
Beatty[d]	1,800	1,900	1,200
Gabbs[d,f]	680	360	320
Pahrump[d]	8,800	15,000	25,000
Tonopah[d]	3,600	3,400	2,600
Lincoln County			
Caliente	1,100	1,200	1,100

a. Population numbers have been rounded to two significant figures.
b. Sources:
   (1) DIRS 100065-NSDO (1998, all).
   (2) DIRS 148031-PIC (1993, all).
   (3) DIRS 148060-Levy (1997, all).
   (4) DIRS 153928-NDA (2000, all).
c. Source: DIRS 155872-Bureau of the Census (2000, place totals).
d. Selected unincorporated towns.
e. N/A = not available.
f. Gabbs unincorporated in May 2001.

employment and about 68 percent of the State employment. During the same year Nye County had an employment base of about 13,000, and the Lincoln County employment base was about 2,000. Clark County should continue to lead employment growth in the region of influence.

Between 1980 and 1990, Clark County added an average of 19,000 jobs a year (Table 3-25). Since 1990 that pace has increased to more than 38,000 new jobs a year. *Total employment* increased 35 percent between 1990 and 1995, adding about 160,000 jobs. In 2000, Clark County added 3,000 jobs a month to its labor force. The services sector, which includes hotels, eating and drinking establishments, and amusement and recreation facilities, is the largest employer in Clark County, representing 45 percent of the employment in 2000.

Although Nye County's employment increased between 1980 and 1990, it declined to about 11,000 in 1995, a decrease of 15 percent (Table 3-26). Employment rebounded and by 2000 there were approximately 13,000 jobs in the county. Services represents the largest employment sector in the Nye County economy. In 2000, services comprised 43 percent of Nye County's employment and retail trade made up an additional 14 percent. Lincoln County's employment declined between 1990 and 1995 after growth during the 1980s (Table 3-27). Employment had declined to about 2,000 positions by 2000. As in Clark and Nye Counties, services represented the largest sector of the Lincoln County economy, about 35 percent. Employment in Federal, State, and local government agencies represented a significant presence in the County's employment, about 29 percent.

Las Vegas, in Clark County, has one of the fastest growing economies in the country. The rapid growth of the Las Vegas area is driven by the gaming and tourism industry. For each hotel room constructed, an employment multiplier effect creates an estimated 2.5 direct and indirect (composite) jobs. About 4,200 hotel rooms were added in 2000 alone. Despite an inventory of more than 124,000 rooms, hotels consistently operate at 90 percent occupancy, reaching 97 percent on weekends.

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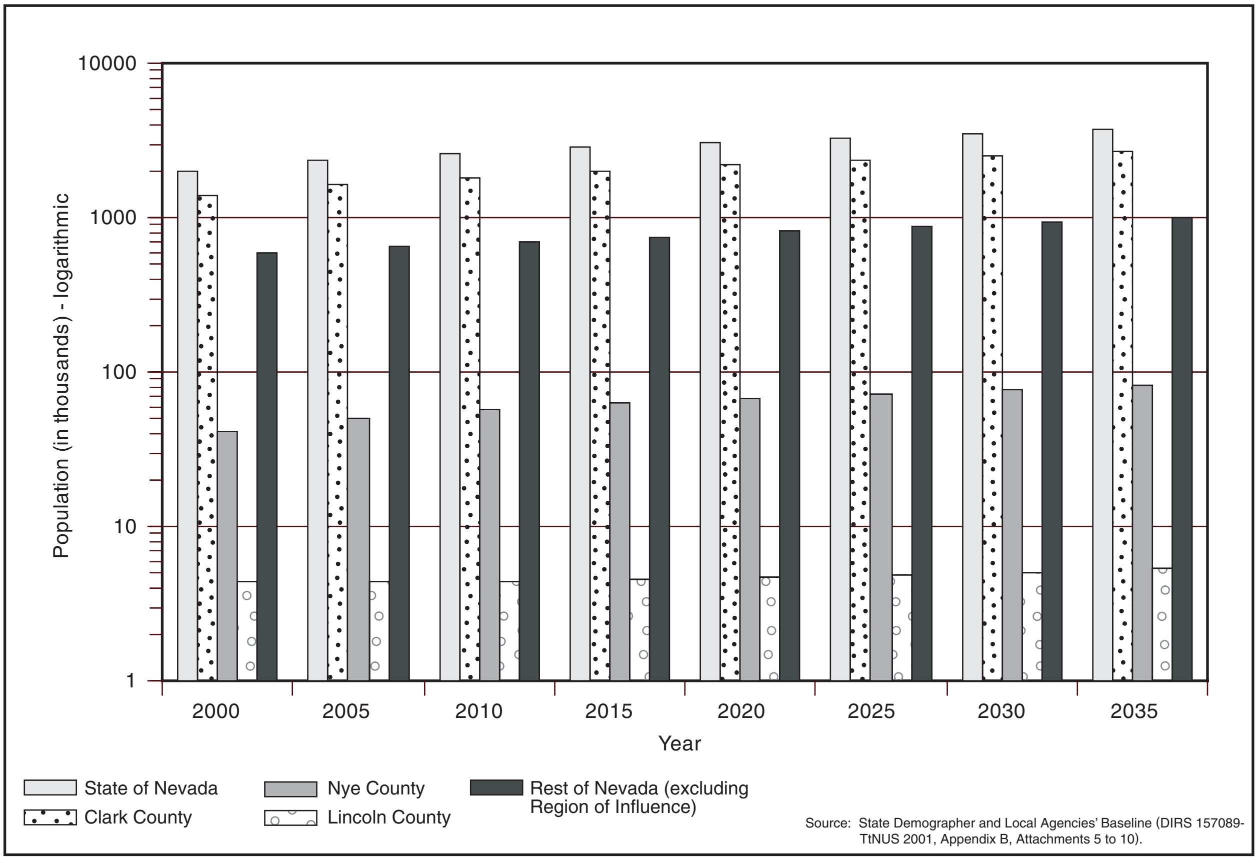

Figure 3-24. Estimated populations to 2035 for the region of influence and the State of Nevada.

Hundreds of new jobs are added to the regional economy each month, and many job seekers have come to the area (primarily Clark County). Some of these new arrivals, however, lack the necessary job skills or experience that area employers require. As a result, Clark County has maintained a healthy, relatively low unemployment rate, but one that remains near State and national averages. In 2000, Clark and Nye Counties had unemployment rates of 4.3 percent and 5.4 percent, respectively (DIRS 155818-NDETR 2001, all). The average in the State of Nevada was about 4.4 percent, and nationwide the unemployment rate was about 4.0 percent. Lincoln County had an unemployment rate above the national average at 6.6 percent (DIRS 155818-NDETR 2001, all). Onsite employment levels at the Exploratory Studies Facility remained relatively constant between 1995 and 2000, and are not likely to fluctuate substantially through the end of site characterization activities.

In 2000, an average of about 2,320 workers (220 work on the site and 2,100 off the site) worked on the Yucca Mountain Project. Most offsite workers are employed in the Las Vegas area (DIRS 155987-DOE 2001, Table 3-1).

As would be expected, projected employment in the region of influence broadly reflects population trends. The number of jobs in Clark County will reach approximately 1.3 million in 2035, up from 840,000 in 2000. Clark County will host 98 percent of the employment opportunities in the three-county region of influence. Nye County will add approximately 10,000 additional workers by 2035 from the 13,000 base in 2000. Lincoln County employment will expand from 2,040 in 2000 to approximately 2,700 in 2035.

Table 3-25. Clark County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	1,300	3,900	6,200	9,400
Mining	590	820	1,200	1,500
Construction	16,000	41,000	53,000	81,000
Manufacturing	7,300	12,000	18,000	21,000
Transportation and public utilities	14,000	21,000	29,000	38,000
Wholesale trade	6,500	14,000	19,000	25,000
Retail trade[d]	44,000	72,000	98,000	134,000
Finance, insurance, and real estate	20,000	32,000	44,000	62,000
Farms	420	400	300	350
Services[d]	120,000	210,000	290,000	374,000
Government				
Federal Government - civilian	4,800	6,900	7,800	8,100
Federal Government - military	11,000	11,000	9,500	10,000
State and local government	22,000	33,000	45,000	66,000
Totals[e]	***268,000***	***458,000***	***621,000***	***830,000***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are included in Retail Trade.
e. Sums may not add to totals because of rounding.

Table 3-26. Nye County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	50	70	110	110
Mining	1,100	2,000	1,400	830
Construction	410	390	560	880
Manufacturing	88	160	250	310
Transportation and public utilities	210	280	280	400
Wholesale trade	25	49	100	180
Retail trade	530	960	1,200	1,800
Finance, insurance, and real estate	360	290	450	510
Farms	220	260	210	260
Services[d]	4,100	7,700	5,200	5,300
Government				
Federal Government - civilian	130	200	200	200
Federal Government - military	100	77	53	81
State and local government	540	930	1,200	2,000
Totals[e]	***7,860***	***13,400***	***11,200***	***12,900***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are included in Retail Trade.
e. Sums may not add to totals because of rounding.

Table 3-27. Lincoln County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	4	30	22	23
Mining	310	30	18	51
Construction	75	47	44	32
Manufacturing	12	10	10	19
Transportation and public utilities	96	88	62	120
Wholesale trade	12	10	17	42
Retail trade	310	250	270	380
Finance, insurance, and real estate	51	47	68	77
Farms	160	180	150	160
Services[d]	380	1,200	869	680
Government				
Federal Government - civilian	25	45	39	36
Federal Government - military	12	12	8	11
State and local government	360	480	560	620
Totals[e]	***1,860***	***2,430***	***2,140***	***2,250***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are contained in Retail Trade.
e. Sums may not add to totals because of rounding.

The 1997 per-capita income of Clark County was about $26,200, near the State's average of about $26,600. The per-capita income in Nye County was $20,400 and in Lincoln County it was $18,400. The U.S. average was $25,300 in the same year (DIRS 155987-DOE 2001, Tables: 1994-1998 Per Capita Income, Nevada vs. Western States; 1970-1998 Total & Per Capita Income in Nevada; and 1989-1997 Per Capita Income in Nevada, by County).

3.1.7.3 Payments-Equal-to-Taxes

Another issue of interest is the DOE Payments-Equal-To-Taxes Program. Section 116(c)(3)(A) of the Nuclear Waste Policy Act, as amended, requires the Secretary of Energy to "…grant to the State of Nevada and any *affected unit of local government* an amount each *fiscal year* equal to the amount such State or affected unit of local government, respectively, would receive if authorized to tax site characterization activities…." The Yucca Mountain Site Characterization Office is responsible for implementing and administering this program for the Yucca Mountain Project. DOE acquired data from the project organizations that purchase or acquire property for use in Nevada, have employees in Nevada, or use property in Nevada. These organizations include Federal agencies, national laboratories, and private firms. Not all of them have a Federal exemption, so they pay the appropriate taxes. The purchases (sales and use tax), employees (business tax), and property (property or possessory use taxes) of the Yucca Mountain Project organizations that exercise a Federal exemption are subject to the Payments-Equal-To-Taxes Program (DIRS 156763-YMP 2001, all).

The actual sales and use taxes, property taxes, and Nevada business taxes paid by Yucca Mountain Project organizations that are not exempted from tax payment obligations for May 1986 through June 2000 have been totaled. These organizations paid sales or use taxes of $2.5 million for purchases consumed in Clark County and $5.1 million in Nye County, paid property or possessory taxes of about $90,000 in Clark County and $37,000 in Nye County, and paid Nevada business taxes of about $810,000 (DIRS 156763-YMP 2001, all).

The Payments-Equal-To-Taxes for sales or use taxes from May 1986 through June 2000 was about $4.4 million for purchases consumed in Clark County and $450,000 in Nye County. For property taxes it was about $940,000 in Clark County, $46 million in Nye County, $8,000 in Lincoln County, and $3,700 in Esmeralda County. For Nevada business taxes (Clark, Nye, Esmeralda, and Lincoln Counties), about $160,000 was paid (DIRS 156763-YMP 2001, all).

3.1.7.4 Housing

Spurred by the rapid population growth and soaring employment opportunities, the residential housing market is strong and steady in the Las Vegas area. From 1992 to 1996, annual sales of new homes exceeded 16,000 units. In 1999, a record 21,200 units were sold. In 2000, 20,500 new homes and 29,500 existing homes were sold. More than 400 residential developers sell properties in the Las Vegas area, leading to a highly competitive market. The competitive environment has kept price increases to the rate of inflation. Eighty-five percent of the new homes sold were priced between $100,000 and $200,000. In 2000, the median price of a new home was about $160,000 and the median price of a resale home was about $132,000. These sale prices are slightly below the national median prices of $165,000 for new homes and $143,500 for existing units. Large master-planned communities are common, and average about 30 percent of the total home sales. Steady employment and population growth should continue to spur demand for housing. Sustained growth will depend on further development of large-scale resort and gaming projects.

The housing stock of Clark County in 1990 was about 320,000 units, which consisted of about 157,000 single-family units, 130,000 multifamily units, and 33,000 mobile homes or other accommodations. About 290,000 of these units were occupied (DIRS 148097-Bureau of the Census 1998, all) resulting in 2.5 persons per household. The number of households in Clark County in 2000 was about 560,000 units (DIRS 155872-Bureau of the Census 2000, all).

The housing stock of Nye County in 1990 was about 8,100 units, which consisted of about 2,300 single-family units, 560 multifamily units, and 5,200 mobile homes or other accommodations. About 6,700 of these units were occupied, resulting in 2.5 persons per household (DIRS 148097-Bureau of the Census 1998, all). The number of households in Nye County in 2000 was about 15,900 (DIRS 155872-Bureau of the Census 2000, all).

The housing stock of Lincoln County in 1990 was about 1,800 units, which consisted of about 1,000 single-family units, 160 multifamily units, and 600 mobile homes or other accommodations. About 1,300 of these units were occupied, resulting in 2.6 persons per household (DIRS 148097-Bureau of the Census 1998, all). The number of households in Lincoln County in 2000 was about 2,200 (DIRS 155872-Bureau of the Census 2000, all).

Because most population and employment growth in the region of influence will occur in Clark County, most housing growth also will occur there. The only other area in the region likely to see large growth is Pahrump in southern Nye County. Housing changes in Lincoln County probably will be minimal in the foreseeable future.

3.1.7.5 Public Services

Education. In the 2000-2001 school year, the region of influence contained about 223 public elementary and middle schools, 37 public high schools, 13 alternative schools, 4 special education schools, an Advanced Technology Academy, an adult education center, and 3 charter schools (DIRS 157141-NDE 2001, all). Clark County opened 11 of these schools in the 2000-2001 school year. The average pupil-teacher ratio was about 21-to-1 for elementary schools and 19-to-1 for secondary schools (DIRS 157142-NDE 2001, all). In 1999, the national pupil-teacher ratio was about 19-to-1 for elementary schools and

15-to-1 for secondary schools (DIRS 155819-NCES 2000, all). Clark County has the tenth-largest school district in the country; during the 2000-2001 school year, Clark County had about 258 schools and nearly 232,000 students (Table 3-28). During the same period, Nye County had approximately 5,300 students, and Lincoln County had about 1,020 students (DIRS 155820-NDE 2001, all).

Table 3-28. Enrollment by school district and grade level.[a,b]

District	Actual 1996-1997[c]	Actual 2000-2001[d]
Clark County		
Prekindergarten	1,100	1,100
Kindergarten	15,000	19,000
Elementary (grades 1-6)	90,000	120,000
Secondary (grades 7-12)	73,000	94,000
District totals[e]	179,000	232,000
Nye County		
Prekindergarten	43	54
Kindergarten	370	360
Elementary (grades 1-6)	2,300	2,500
Secondary (grades 7-12)	2,200	2,300
District totals[e]	4,970	5,290
Lincoln County		
Prekindergarten	22	15
Kindergarten	57	62
Elementary (grades 1-6)	400	370
Secondary (grades 7-12)	630	570
District totals[e]	1,110	1,020

a. Figures include ungraded students who are enrolled in school for special education and students who cannot be assigned to a grade because of the nature of their conditions; Prekindergarten refers to 3- and 4-year-old minors receiving special education.
b. Enrollment numbers have been rounded to two significant figures; totals to three significant figures.
c. Source: DIRS 157146-NDE (2001, all).
d. Source: DIRS 155820-NDE (2001, all).
e. Totals might not equal sums of values due to rounding.

Health Care. Health care services in the region of influence are concentrated in Clark County, particularly in the Las Vegas area. In 2000, Clark County had nine community hospitals (DIRS 156286-Medical Central Online 2001, all), including the newly opened 141-bed Siena campus of St. Rose Dominican (DIRS 156288-Babula 2000, all) and several specialized care facilities. Several major health care providers have proposed new hospitals or expansions of existing facilities and are awaiting various approval processes. Voters rejected a proposed Children's Hospital in June 2001. Although Nye County has one hospital in Tonopah, most people in the southern part of the county use local clinics or go to hospitals in Las Vegas. Lincoln County has one hospital in Caliente (DIRS 156286-Medical Central Online 2001, all). Table 3-29 lists hospital use in the region of influence.

Medical services are available at the Nevada Test Site for Exploratory Studies Facility personnel; these services include two paramedics and an ambulance in Area 25. Backup services are on call from other Test Site locations. In addition, the Nevada Test Site provides medical services for Yucca Mountain Project workers at a clinic in Mercury, which has no overnight capability. When patients need urgent care, the Yucca Mountain Project relies on the helicopter "Flight for Life" and "Air Life" operations from Las Vegas. In emergencies, Area 25 can call on Nellis Air Force Base or Nye County for help.

Law Enforcement. The Las Vegas Metropolitan Police Department is responsible for law enforcement in Clark County with the exceptions of the Cities of North Las Vegas, Henderson, Boulder City, and Mesquite, which have their own police departments. The Las Vegas police department is the largest law enforcement agency in Nevada; in 2001, it had about 2,620 employees including 1,750 commissioned officers; a ratio of about 2.5 employees or 1.6 commissioned officers per 1,000 residents. In 2000, the Nye County Sheriff Department had 113 employees, a ratio of 3.5 employees per 1,000 residents, and Lincoln County had 17 sheriff department employees serving an area of 27,500 square kilometers (10,600 square miles), a ratio of 4.0 employees per 1,000 residents. In comparison, the national officer-to-population ratio is 2.4 officers per 1,000 residents, (DIRS 148129-FBI 1996, pp. 1 to 3).

Table 3-29. Hospital use by county in the region of influence.[a]

County	1995[b]	1998	2000
Clark			
Population	1,000,000	1,260,000[c]	1,380,000[d]
Average number of beds	2,100	2,400[e]	2,600[f,g,h]
Beds per 1,000 residents	2.2	1.9[f]	1.9[e]
Patient-days	530,000	607,000[c]	N/A
Nye			
Population	24,000	29,700[c]	32,000[d]
Average number of beds	21	10[e]	42[f,g]
Beds per 1,000 residents	0.86	0.33[f]	1.3
Patient-days	1,900	560[e]	N/A
Lincoln			
Population	3,900	4,200[c]	4,200[d]
Average number of beds	4	4[e]	20[f,g]
Beds per 1,000 residents	1.0	0.95[f]	4.8
Patient-days	360	300[e]	N/A

a. All displayed numbers have been rounded to two or three significant figures.
b. Source: DIRS 103451-Rodefer et al. (1996, pp. 214 to 216).
c. Source: DIRS 153928-NDA (2000, all).
d. Source: DIRS 155872-Bureau of the Census (2000, County totals).
e. Average number of beds and patient days (DIRS 155910-State of Nevada 1999, all).
f. DIRS 156286-Medical Central Online (2001, all).
g. Actual, staffed number of beds.
h. DIRS 156288-Babula (2001, all).

Protection. A combination of fire departments provides protection in the region of influence; these include the Clark County, Las Vegas, and North Las Vegas fire departments and several other city, county, and military departments. In 2001, the Clark County Fire Department had about 500 paid and 390 volunteer firefighters. The Las Vegas Fire Department had 334 paid firefighters and the North Las Vegas Fire Department had 259 firefighters. In 2001, Nye County and Lincoln County met fire suppression needs with volunteers from the individual communities in the counties. The national average is 4.1 firefighters (paid and volunteer) per 1,000 residents.

3.1.8 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The public health and safety region of influence consists of the number of persons residing within an 80-kilometer (50-mile) radius of the repository site at the end of site characterization. The estimated population in 2000 is about 34,000, which could grow to an estimated 76,000 by 2035. Both the population estimate for 2000 and the projection for 2035 are based on the State Demographer and Local Agencies' Baseline as described in Section 3.1.7, and are distributed over the 80-kilometer (50-mile) radius as shown in Figure 3-25. The region of influence includes parts of Nye, Clark, Lincoln, and Esmeralda Counties in Nevada, as well as Inyo County in California (Figure 3-25). Potentially affected workers include those at the repository site and at nearby Nevada Test Site facilities. This section describes the existing radiation environment and the baseline cancer incidence in the region of influence. Unless otherwise noted, the *Environmental Baseline File for Human Health* (DIRS 104544-CRWMS M&O 1999, all) is the basis of the information in this section.

Section 3.1.8.1 describes the various radiation sources that make up the radiation environment. Section 3.1.8.2 describes the existing radiation environment in the Yucca Mountain region. Section 3.1.8.3 describes the health-related mineral issues encountered during site characterization activities. Section 3.1.8.4 describes the worker industrial safety experienced from site characterization activities.

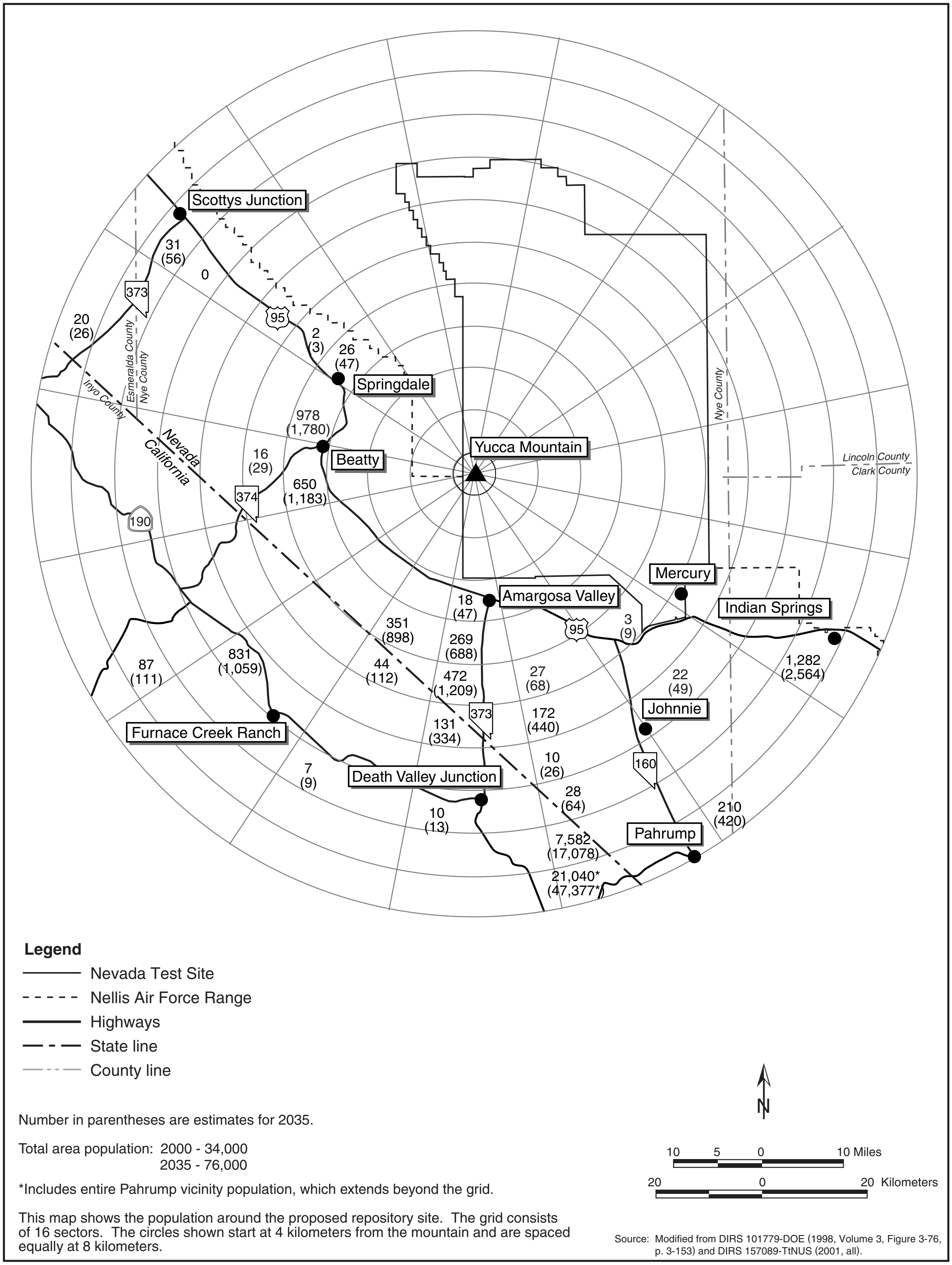

Figure 3-25. Population distribution within 80 kilometers (50 miles) of the proposed repository site, 2000 estimate and 2035 projection (in parentheses), based on the State Demographer and Local Agencies' Baseline.

3.1.8.1 Radiation Sources in the Environment

Types of Radiation. There are ambient levels of radiation at and around the site of the proposed repository just as there are around the world. All people are inevitably exposed to the three sources of *ionizing radiation*: those of *natural* origin unaffected by human activities, those of natural origin but affected by human activities (called *enhanced natural* sources), and *manmade* sources. Natural sources (natural background radiation) include *cosmic radiation* from space, *cosmogenic radionuclides* produced when cosmic radiation interacts with matter in the atmosphere or ground, and naturally occurring, long-lived primordial radionuclides in the Earth's mantle. Enhanced natural sources include those that can increase exposure as a result of human actions, deliberate or otherwise. For example, a mill tailings pile from a uranium extraction process probably would contain concentrated levels of naturally occurring radionuclides. A variety of radiation exposures, generally smaller than those caused by natural sources, result from manmade sources including nuclear medicine, medical *X-rays*, and consumer products.

Natural background radiation is the largest contributor to the average radiation dose of individuals. The natural occurrence of cosmic radiation, cosmogenic radionuclides, and primordial radionuclides varies throughout the world depending on such factors as altitude and geology. External radiation comes from all three of these natural sources, but cosmic radiation and radiation from primordial radionuclides are the largest dose contributors. Cosmic radiation consists of charged particles (primarily protons from extraterrestrial sources) that have sufficiently high energies to generate secondary particles that have direct and indirect ionizing properties. The three main primordial radionuclide contributors to external terrestrial gamma radiation are potassium-40 and the members of the thorium and uranium decay series. Most external terrestrial gamma radiation comes from the top 20 centimeters (8 inches) of soil, with a small contribution from airborne radon decay products. Although of smaller importance to natural external dose than the other two mechanisms, two cosmogenic radionuclides, sodium-22 and beryllium-7, produce quantifiable external doses in humans.

Internal radiation dose from natural sources comes primarily from the primordial radionuclides and their decay products. The largest individual source of internal dose comes from the inhalation of radon-222 and its decay products, which are all members of the uranium-238 decay series. This exposure comes mainly from inhalation of these radionuclides in indoor air, coming from the soil underneath buildings. All of the primordial radionuclides are in the body in various concentrations, incorporated by ingesting or inhaling these radionuclides in air, water, and all types of food products. In addition, two cosmogenic radionuclides—tritium (hydrogen-3) and carbon-14—produce quantifiable internal doses. Table 3-30 lists estimated radiation doses from natural sources to individuals in the region of influence and other locations in the United States.

Effects of Radiation Exposure. The effect of radiation on people depends on the kind of radiation exposure (alpha and beta particles, and X-rays and gamma rays), the total amount of tissue exposed to radiation, and the duration of the exposure. The amount of radiant energy imparted to tissue from exposure to ionizing radiation is referred to as *absorbed dose*. The sum of the absorbed dose to each tissue, when multiplied by certain quality and weighting factors that take into account radiation quality and different sensitivities of the various tissues, is referred to as *effective dose equivalent* and is expressed in *rem*. The Code of Federal Regulations contains further discussion of DOE radiation protection standards and methods of dose assessment (10 CFR Part 835).

An individual can be exposed to radiation from outside or inside the body because radioactive materials can enter the body by ingestion or inhalation. External dose is different from internal dose in that it is delivered only during the actual time of exposure. An internal dose, however, continues to be delivered as long as the radioactive source is in the body (although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes usually decrease the *dose rate* with the passage of time).

TERMS USED IN RADIATION DOSE ASSESSMENT

Curie: A unit of radioactivity equal to 37 billion disintegrations per second; also a quantity of any nuclide or mixture of nuclides having 1 curie of radioactivity.

Picocurie per liter (or gram): A unit of concentration measure describing the amount of radioactivity (in picocuries) in a volume (or mass) of a given substance [typically, air or water (by volume) or soil (by mass)]. A picocurie is one one-trillionth of a curie.

Rad: The unit of absorbed radiation dose in terms of energy. One rad is equal to an absorbed dose of 100 ergs per gram.

Rem: The unit of effective dose equivalent from ionizing radiation to the human body. It is used to express the amount of radiation to which a person has been exposed. The effective dose equivalent in rem is equal to the absorbed dose in rad multiplied by quality and weighting factors that are necessary because biological effects can vary both by the type of radiation (even of the same deposited energy) and by the specific tissue exposed.

Total effective dose equivalent: Often generically referred to simply as dose, it is an expression of the radiation dose received by an individual from external radiation and from radionuclides internally deposited in the body. All doses presented in this document are in terms of total effective dose equivalent.

Latent cancer fatality: A death resulting from cancer that has been caused by exposure to ionizing radiation. There is typically a latent period between the time of radiation exposure and the time the cancer cells become active.

Table 3-30. Radiation exposure from natural sources (millirem per year).[a]

	Annual dose (effective dose equivalent)					
					Region of influence	
Source	U.S. average	Aiken[b]	Oak Ridge[c]	Las Vegas	Amargosa Valley	Beatty
Cosmic and cosmogenic	28	29	36	(d)	40	(d)
Terrestrial	28	24	51	89	56	150
Radon in homes (inhaled)[e]	200	200	200	200	200	200
In body	40	40	40	40	40	40
Totals[f]	***300***	***290***	***330***	***330***	***340***	***390***

a. Sources: DIRS 146592-Black and Townsend (1998, p. 4-31); DIRS 103208-DOE (1995, p. 4-211 and 4-394) DIRS 103207-DOE (1995, Figure 3-16); DIRS 101855-NCRP (1987, Section 2); DIRS 153135-DOE (1999, p. A-9).
b. Aiken, South Carolina, is the location of the DOE Savannah River Site.
c. Oak Ridge, Tennessee, is the location of the DOE Oak Ridge Reservation.
d. Included in the terrestrial source.
e. Value for radon is an average for the United States.
f. Totals might differ from sums due to rounding.

Radiation can cause a variety of adverse health effects in people. The following discussion is an overview of the method commonly used to estimate effects of radiation exposure; Appendix F contains more detailed information. At low doses, the most important adverse health effect for depicting the consequences of environmental and occupational radiation exposures (which are typically low doses) is the potential inducement of cancers that can lead to death in later years. This effect is referred to as *latent cancer fatalities* because the cancer can take years to develop and for death to occur, and might never actually be the cause of death.

The collective dose to an exposed population is calculated by summing the estimated doses received by each member of the exposed population. This is referred to as a *population dose*. The total population dose received by the exposed population is measured in *person-rem*. For example, if 1,000 people each received a dose of 0.001 rem, the population dose would be 1.0 person-rem (1,000 persons multiplied by 0.001 rem equals 1.0 person-rem). The same population dose (1.0 person-rem) would result if 500 people each received a dose of 0.002 rem (500 persons multiplied by 0.002 rem equals 1 person-rem).

The factor used in this EIS to relate a dose to its potential effect is 0.0004 latent cancer fatality per person-rem for workers and 0.0005 latent cancer fatality per person-rem for individuals among the general population (DIRS 101856-NCRP 1993, p. 3). The latter factor is slightly higher because some individuals in the public, such as infants, might be more sensitive to radiation than workers. These risk factors have also been endorsed by the International Commission on Radiological Protection, Nuclear Regulatory Commission, and National Council on Radiation Protection and Measurements. The Environmental Protection Agency recently published an age-specific risk factor of 0.000575 latent cancer fatality per person-rem (DIRS 153733-EPA 2000, Table 7.3, p. 179), which is discussed in Appendix F. Both the Agency and DOE recognize that there are large uncertainties associated with these risk factors. As a consequence, DOE believes that the 15-percent difference in these risk factors (between 0.0005 and 0.000575) is well within other uncertainties and would provide little additional information to the decisionmaking process supported by this document. For these reasons, in its National Environmental Policy Act documents, DOE has continued to use risk factors recommended by the International Commission on Radiological Protection.

These concepts can be used to estimate the effects of exposing a population to radiation. For example, if 100,000 people were each exposed only to background radiation (0.3 rem per year), 15 latent cancer fatalities could occur as a result of 1 year of exposure (100,000 persons multiplied by 0.3 rem per year multiplied by 0.0005 latent cancer fatality per person-rem equals 15 latent cancer fatalities).

Calculations of the number of latent cancer fatalities associated with radiation exposure do not normally yield whole numbers and, especially in environmental applications, can yield numbers less than 1.0. For example, if 100,000 people were each exposed to a total dose of only 1 millirem (0.001 rem), the population dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons multiplied by 0.001 rem multiplied by 0.0005 latent cancer fatality per person-rem equals 0.05 latent cancer fatality).

The *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people is 0.05. In most groups, nobody (zero people) would incur a latent cancer fatality from the 1-millirem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The average number of deaths over all the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 is 0.25). The most likely outcome is no latent cancer fatalities in these different groups.

To aid in decisionmaking, DOE has applied these same concepts in estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The probability of a latent cancer fatality corresponding to a single individual's exposure to 0.3 rem a year over a (presumed) 70-year lifetime is:

$$\begin{aligned}\text{Probability of a latent cancer fatality} &= 1 \text{ person} \times 0.3 \text{ rem per year} \times 70 \text{ years} \\ &\quad \times 0.0005 \text{ latent cancer fatality per person-rem} \\ &= 0.011 \text{ probability of a latent cancer fatality.}\end{aligned}$$

Again, this should be interpreted in a statistical sense; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1-percent chance that the individual would incur a latent fatal cancer. For comparison purposes, statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer from all causes (DIRS 153066-Murphy 2000, p. 83).

3.1.8.2 Radiation Environment in the Yucca Mountain Region

Ambient radiation levels from cosmic and terrestrial sources at Yucca Mountain are higher than the U.S. average. The higher elevation at Yucca Mountain results in higher levels of cosmic radiation due to less shielding by the atmosphere. The U.S. average for cosmic, cosmogenic, and terrestrial radiation exposures is 56 millirem per year (Table 3-30). The exposures at the Yucca Mountain ridge and Yucca Mountain surface facilities are about 160 and 150 millirem per year, respectively. Moreover, there are higher amounts of naturally occurring radionuclides in the soil and parent rock of this region than in some other regions of the United States, which also results in higher radiation doses.

The surface environment, or soil, of Yucca Mountain contains the following naturally occurring radionuclides (DIRS 146183-CRWMS M&O 1996, all):

Radionuclide	Dry weight concentration (picocuries per gram)
Uranium-238	0.002 to 0.22
Radium-226	0.77 to 3.3
Thorium-232	0.17 to 0.92
Potassium-40	18 to 35

DOE measured external dose rates on the surface with thermoluminescent dosimeters at 64 to 127 millirem per year. This compares to an average annual dose from cosmic, cosmogenic, and terrestrial radiation in the Amargosa Valley of 96 millirem per year (Table 3-30).

With respect to the subsurface environment, the content of naturally occurring uranium and thorium in rock at Yucca Mountain has been measured at 2 to 6 and 15 to 35 milligrams per kilogram, respectively (DIRS 105946-Vaniman et al. 1996, Table 1-5; DIRS 155605-Bush, Bunker, and Spengler 1983, Table 1, pp. 4 to 7). The activity concentrations for uranium-238 are about 0.7 to 1.7 *picocurie* per gram, and for thorium-232 they are about 1.7 to 3.7 picocuries per gram. The activity concentrations of uranium and thorium decay products, including various isotopes of radium, should be in equilibrium in undisturbed rock and have the same activity concentration as the respective precursor radionuclide. The potassium content of the rock ranges from about 1 to 5 percent (DIRS 155605-Bush, Bunker, and Spengler 1983, Table 1, pp. 4 to 7). Because the natural abundance of radioactive potassium-40 is about 0.012 percent, the potassium-40 content of the rock ranges from about 1.4 to 5.9 milligrams per kilogram, an activity concentration of 10 to 41 picocuries per gram. Appendix F, Section F.1.1.6 discusses the range of background external radiation levels in the Exploratory Studies Facility. External exposure rates range from 0.014 to 0.038 millirem per hour and the median dose to a subsurface worker would be about 40 millirem per year.

The Yucca Mountain Project and the DOE Nevada Operations Office (in conjunction with the Environmental Protection Agency) conduct environmental surveillances around the Nevada Test Site. This monitoring has identified no radioactivity attributable to current operations at the Test Site. It did detect trace amounts of manmade radionuclides from worldwide nuclear testing in milk, game, and foods and in soil. Even though the monitoring has not detected ongoing releases to the environment related to the Test Site, DOE has made quantitative estimates of offsite doses from releases from past weapons testing activities at the Nevada Test Site (DIRS 155569-Townsend and Grossman 2000, pp. 7-1 to 7-4). DOE discusses estimates of radiation doses to the general population from past test site activities at the end of this section. Sources of ongoing releases at the Nevada Test Site include water containment ponds and contaminated soil resuspension. The estimated maximum annual radiation dose to a hypothetical individual in Springdale, Nevada [approximately 14 kilometers (9 miles) north of Beatty on U.S. 95], from airborne radioactivity is 0.12 millirem and 0.38 person-rem to the population within 80 kilometers (50 miles) of Nevada Test Site airborne emission sources. The maximum hypothetical-individual dose, which is about 1 percent of the 10-millirem-per-year dose limit that the Environmental Protection Agency established for a member of the public from emissions to the air from manmade sources (40 CFR Part 61), is conservative because data from offsite surveillance do not support doses of this magnitude.

Workers in the Exploratory Studies Facility can inhale naturally occurring radon-222 (a radioactive *noble* gas that is a decay product of naturally occurring uranium in rock) and its radioactive decay products. Radon concentration measurements during working hours, at a location representative of repository conditions, ranged from about 0.24 to 65 picocuries per liter (5th to 95th percentile), with a median concentration of about 13 to 17 picocuries per liter (DIRS 156114-Carl 2001, all). The median annual dose to Exploratory Studies Facility workers from inhalation of radon and decay products underground was estimated to be about 15 millirem, with an average of about 40 millirem and range from 0 to 180 millirem (5th to 95th percentile) (DIRS 156118-Gonzalez 2001, all). Appendix F, Section F.1.1.6, contains additional information on the estimated underground dose to *involved workers* from radon.

Workers in the Exploratory Studies Facility are also exposed to external gamma radiation from radon decay products and other naturally occurring radionuclides. Ambient radiation monitoring in this facility indicated a dose rate from background sources of radionuclides in the drift walls of about 0.014 to 0.038 millirem per hour, which would be about 50 millirem per year for a 2000-hour work year (see Appendix F, Section F.1.1.6).

Naturally occurring radon-222 and decay products are released from the Exploratory Studies Facility in the exhaust ventilation air. The estimated annual release of radon and decay products is about 80 curies. The estimated annual dose to an individual 20 kilometers (12 miles) south of the repository is less than 0.1 millirem. The estimated annual dose to the population within 80 kilometers (50 miles) is about 10 person-rem. These doses are small percentages of the dose from natural sources shown in Table 3-30. Appendix G contains additional information on the estimated releases of radon from the repository.

Effects from Past Nevada Test Site Weapons Testing. The history of the testing of nuclear weapons can be broadly divided into two eras, the era in which testing was predominantly performed above ground (1951 to 1961) and the era in which testing was performed predominantly underground (1961 to 1992). Since 1992, there has been a moratorium on nuclear testing. DOE described the activities at the Nevada Test Site in a previous NEPA document, the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all).

Radiation doses to the population surrounding the Nevada Test Site have been the subject of several reports since the inception of the nuclear weapons testing program. For example, the National Council on Radiation Protection and Measurements published estimates of effective dose equivalents in its Publication 93 (DIRS 101855-NCRP 1987, all), in which it reported an average dose commitment to each individual in the United States from all weapons testing of approximately 250 millirem received up through 2000 with very little received thereafter from deposition in the body.

A more recent report prepared by the National Cancer Institute (DIRS 152469-Institute of Medicine and National Research Council 1999, all) evaluated doses to the thyroid glands of individuals from iodine-131 but did not estimate doses from other radionuclides. That report calculated thyroid doses for each series of nuclear weapons tests that had occurred and concluded that approximately 98 percent of the dose to the population due to iodine-131 deposition in the thyroid gland was from the atmospheric weapons testing, with approximately 2 percent due to underground testing.

The calculated average dose to the thyroid gland of individuals in Nevada ranged from 0.5 *rad* to 5.0 rad (which is close to 0.5 rem to 5.0 rem) for residents who lived in the area during all the tests. The

National Cancer Institute further estimated an exposed population of 213,000 for iodine-131 exposure. The majority of that exposed population resided outside the region of influence evaluated in this EIS at the time of their exposure.

As discussed by the National Council on Radiation Protection and Measurements (DIRS 101855-NCRP 1987, all), because of the time that has elapsed since the occurrence of atmospheric nuclear weapons testing, much of the radioactivity in the environment with the potential to cause appreciable radiation dose has undergone decay. Therefore, individuals with the greatest potential for appreciable radiation doses from weapons testing would be those who were born before the 1960s, with less potential for those born later.

3.1.8.3 Health-Related Mineral Issues Identified During Site Characterization

Certain minerals known to present a potential risk to worker health are present in the volcanic rocks at Yucca Mountain (DIRS 101779-DOE 1998, Volume 1, pp. 2-24 and 2-25). The risks are generally related to potential exposures caused by inhalation of airborne particulates (dust). Some of the minerals represent a hazard commonly associated with underground construction, whereas others are rare and less well known.

Crystalline silica (silicon dioxide) comes in several forms—among them quartz, tridymite, and cristobalite. Inhaling silica dust causes a disease called *silicosis* that damages an area of the lungs called the air sac (alveoli) (DIRS 103243-EPA 1996, all). The presence of silica dust in the alveoli causes a defensive reaction that results in the formation of scar tissue in the lungs. This scar tissue can reduce overall lung capacity.

DOE typically performs evaluations of exposure to crystalline silica at Yucca Mountain for cristobalite that encompass potential impacts from exposure to other forms of crystalline silica. The repository host rock has a cristobalite content ranging from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). The American Conference of Governmental Industrial Hygienists has established Threshold Limit Values for various forms of crystalline silica (DIRS 103070-ACGIH 1999, p. 61). These limits are based on an 8-hour day and 40-hour week and, therefore, could be exceeded for a short period—as long as the average time spent by a worker is below the limit. The Threshold Limit Values for respirable cristobalite dust and quartz dust are 0.05 and 0.1 milligram per cubic meter, respectively. In addition, crystalline silica has been listed by the World Health Organization as a *carcinogen* (DIRS 100046-IARC 1997, p. 41).

Normal underground mechanical excavation produces dust when the rock is broken loose from the face. Dust is also generated when the broken rock is transferred to railcars or conveyors, or a storage pile. Dust can also be generated by wind erosion of excavated rock storage piles. Excavation activities during site characterization have caused exceedances of crystalline silica Threshold Limit Values at specific work locations. Workers at these locations were required to wear respirators. DOE will use the experience gained during Exploratory Studies Facility activities to design engineering controls to minimize future exposures.

Erionite is an uncommon zeolite mineral that the International Agency for Research on Cancer recognized as a human carcinogen in 1987; at Yucca Mountain, it occurs primarily in the basal vitrophyre of the Topopah Spring tuff and in isolated zones of the Tiva Canyon tuff (see Section 3.1.3). Even at low concentrations erionite is believed to be a potent carcinogen capable of causing mesothelioma, a form of lung cancer. As a result of its apparent carcinogenicity, erionite could pose a risk if encountered in quantity during underground construction, even with standard modern construction practices. Because erionite appears to be absent or rare at the proposed repository depth and location, most repository operations should not be affected. However, repository workers would take precautions (for example, dust suppression, air filters, personal protective gear) during construction when penetrating horizons in which erionite could occur, such as in the basal vitrophyre of the Topopah Spring tuff.

A number of other minerals present at Yucca Mountain might have associated health risks if prolonged exposures occur; however, there is no evidence suggesting a link to cancer. Therefore, the International Agency for Research on Cancer has ranked these substances not classifiable (DIRS 100046-IARC 1997, all). Some of the minerals identified and considered in establishing health and safety practices for potential repository operations include the zeolite group minerals mordenite (which is fibrous and similar in some respects to erionite), clinoptilolite, heulandite, and phillipsite. Because there is no known risk associated with the other zeolite minerals, and because they occur primarily in nonwelded units below the repository horizon, they probably do not represent a large risk. The measures implemented to mitigate risk from silica (for example, dust suppression, air filters, personal protective gear) should also protect workers from exposure to other minerals.

3.1.8.4 Industrial Health and Safety Impacts During Construction of the Exploratory Studies Facility

During Yucca Mountain site characterization activities, health and safety impacts to workers have resulted from common industrial hazards (such as tripping and falling). The categories of worker impacts include total *recordable* incidents, lost workdays, and fatalities. Recordable incidents or cases are occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) *lost workday cases* (nonfatal), and (3) incidents that result in the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Site characterization activities at Yucca Mountain have had no involved worker fatalities. DOE has compiled statistics for the other types of health and safety impacts in accordance with the regulations of the Occupational Safety and Health Administration (29 CFR Part 1904) (see Appendix F, Section F.2). These statistics cover the 30-month period from the fourth quarter of 1994 through the first quarter of 1997. DOE selected this period because there was high onsite work activity in which the tunnel-boring machine was in operation in the Exploratory Studies Facility. DOE expects this condition to be characteristic of the types of activities that would occur during the construction of the surface facilities and the development of the emplacement drifts. Table 3-31 lists the industrial health and safety loss statistics for industry, general construction, general mining, and the Yucca Mountain site.

Table 3-31. Comparison of health and safety statistics for mining activities from the Bureau of Labor Statistics to those for Yucca Mountain during excavation of the Exploratory Studies Facility.[a]

Statistic	Total industry[b]	General construction[b]	General mining[b]	Yucca Mountain experience for involved workers[c]
Total recordable cases rate	7.1	9.5	5.9	6.8
Lost workday cases rate	3.3	4.4	3.7	4.8
Fatality rate	Not available	Not available	Not available	0.0[d]

a. Statistics based on 100 full-time equivalent work years or 200,000 worker hours.
b. Source: DIRS 148091-BLS (1998, all).
c. Source: Appendix F, Section F.2.
d. There have been no fatalities on the Yucca Mountain Project. However, the fatality rate obtained from the entire DOE CAIRS database for industrial activities is 0.0029 per 100 full-time equivalent work years.

3.1.9 NOISE AND VIBRATION

The region of influence for noise includes existing residences in the Yucca Mountain region and at the approximate boundary of the analyzed land withdrawal area. Noise comes from either natural or manmade sources. DOE has evaluated existing noise conditions in the Yucca Mountain region and has compiled the detected ranges of noise levels at different locations under differing conditions.

3.1.9.1 Noise Sources and Levels

Yucca Mountain is in a quiet desert environment where natural phenomena such as wind, rain, and wildlife account for most background noise. The acoustic environment is typical of other desert environments where average day-night sound-level values range from 22 decibels on calm days to 38 decibels on windy days (DIRS 102224-Brattstrom and Bondello 1983, p. 170).

Manmade noise occurs periodically in the area as vehicles travel to and from Yucca Mountain, from site characterization activities at the operations areas, and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain operations areas were consistent with noise levels associated with industrial operations [sound levels from 44 to 72 decibels (A-weighted)] (DIRS 101531-Brown-Buntin 1997, pp. 4-6). Table 3-32 lists estimated sound-level values for Yucca Mountain, nearby communities and cities, and other environments.

Table 3-32. Estimated sound levels in southern Nevada environments.[a]

Environment	Sound level[b] (decibels)
Calm day at Yucca Mountain	22
Windy day at Yucca Mountain	38
Rural communities (Panaca, Hadley, Rachel, Crystal Springs, Ash Springs, Cactus Springs, Alamo, Jean, Goodsprings, Sandy)	40 - 47
Small towns or rural communities along busy highways (Beatty, Indian Springs, Pahrump, Amargosa Valley, Caliente, Tonopah, Goldfield, Mercury) and at the intersection of proposed transportation routes to Yucca Mountain	45 - 55
Suburban parts of Las Vegas	52 - 60
Urban parts of Las Vegas	56 - 66
Dense urban parts of Las Vegas with heavy traffic	64 - 74
Under flight path at McCarran International Airport (0.8 to 1.6 kilometers[c] from runway)	78 - 88

a. Source: Modified from DIRS 101821-EPA (1974, p. 14); DIRS 102224-Brattstrom and Bondello (1983, p. 170).
b. Day-night average sound level.
c. About 0.5 to 1 mile.

3.1.9.2 Regulatory Standards

With the exception of prohibiting nuisance noise, neither the State of Nevada nor local governments have established numerical noise standards. Nevertheless, many Federal agencies use average day-night sound levels as guidelines for land-use compatibility and to assess the impacts of noise on people. Many agencies, including the Environmental Protection Agency, recognize an average day-night sound level of 55 decibels (A-weighted) as an outdoor goal for protecting public health and welfare in residential areas (DIRS 101821-EPA 1974, p. 3). This noise level, which has been established by scientific consensus, is not a regulatory criterion in Nevada, and could protect against activity interference and annoyance. While Nevada does not have a noise code, daytime and nighttime noise standards adopted by Washington State (WAC-173-60 and 70) for residential and commercial areas can serve as benchmarks for evaluating potential impacts based on land use. These benchmarks are 60 decibels for residential use (nighttime reduction to 50 decibels), 65 decibels for light commercial, and 70 decibels for industrial zones. As required, DOE monitors noise levels in worker areas, and a hearing protection program has been in place during site characterization. Hearing protection is used as a supplement to engineering controls, which are the primary method of noise suppression.

Sound levels that cause annoyance in people vary greatly by individual and background conditions. However, the threshold for hearing hazard, which depends on the frequency of the sound, ranges from around 65 decibels at a frequency of 4,000 hertz to about 88 decibels at frequencies of 125 and 8,000 hertz (DIRS 155778-Melnick 1998, Vol. 12, p. 18). These threshold levels assume continuous exposure for periods of hours. High risk for hearing loss occurs at 120 decibels and can result from short-term exposure of seconds to minutes. Ground transportation activities such as those associated with the Proposed Action (either rail or heavy-haul trucks) would not propagate noise levels of this magnitude to the environment.

3.1.9.3 Vibration

Ground vibration is an element of environmental assessment. Many natural phenomena (wave action on beaches, strong winds, earthquakes, etc.) as well as human activities (construction, transportation, military activities, etc.) can contribute to ground vibration. As a consequence, there is a component of background vibration that exists, generally higher in large cities than in rural communities, and lower in areas more distant from human activities. This vibration component can be altered by a change in site activities.

There are two measurements for evaluating ground vibration: peak particle velocity and root-mean-square velocity (DIRS 155547-HMMH 1995, p. 7-3). *Peak particle velocity* is the maximum instantaneous positive or negative peak of the vibration signal, measured as a distance per time (such as millimeters or inches per second). This measurement has been used historically to evaluate “shock”-wave type vibrations from actions like blasting, pile driving, and mining activities, and their relationship to building damage. The root-mean-square level is an average or smoothed vibration amplitude, commonly measured over 1-second intervals. It is expressed on a log scale in decibels (VdB) referenced to 0.000001 (10^{-6}) inch per second and is not to be confused with noise decibels. It is more suitable for addressing human annoyance and characterizing background vibration conditions because it better represents the response time of humans to ground vibration signals.

A typical background level of ground vibration is 52 VdB, and the human threshold for the perception of ground vibration is 65 VdB (DIRS 148155-Hanson, Saurenman, and Towers 1998, p. 46.17). There are three ground vibration impacts of general concern: human annoyance, damage to buildings, and interference to vibration-sensitive activities. Three categories of buildings and associated human activities have been established for the assessment of annoyance or interference impacts from ground vibration (DIRS 155547-HMMH 1995, pp. 8-2 to 8-3). Table 3-33 lists these categories along with associated benchmark vibration levels at which adverse impacts might be likely. An important element of the criteria for human disturbance is the frequency of distinct ground vibration events; the more events, the higher the likelihood of annoyance. Most environmental evaluations have focused on mass transit, where there is a high frequency of events.

Vibration criteria for structural damage in fragile or extremely fragile buildings have separate structural criteria based on peak particle velocity and an approximation of VdB that have been segregated into impulse and rail impacts. Table 3-33 lists these criteria. Building damage from ground vibration, which is rare, is associated with vibration levels that are unpleasant or disturbing long before there is any possibility of damage to the building.

Background levels of ground vibration at the Yucca Mountain site are low. Other than site characterization-related activities, there is basically a lack of the classical, manmade sources of ground vibration impacts; that is, impacts from pile driving, heavy earth-moving equipment (particularly equipment with metal tracks), and blasting.

NOISE MEASUREMENT

What are *sound* and *noise*?

When an object vibrates it possesses energy, some of which transfers to the air, causing the air molecules to vibrate. The disturbance in the air travels to the eardrum, causing it to vibrate at the same frequency. The ear and brain translate the vibration of the eardrum to what we call *sound*. *Noise* is simply unwanted sound.

How is sound measured?

The human ear responds to sound pressures over an extremely wide range of values. The range of sounds people normally experience extends from low to high pressures by a factor of 1 million. Accordingly, scientists have devised a special scale to measure sound. The term decibel (abbreviated dB), borrowed from electrical engineering, is the unit commonly used.

Another common sound measurement is the A-weighted sound level, denoted as dBA. The A-weighting accounts for the fact that the human ear responds more effectively to some pitches than others. Higher pitches receive less weighting than lower ones. Most of the sound levels provided in this EIS are A-weighted; however, some are in decibels due to lack of information on the frequency spectrum of the sound. The scale to the right provides common references to sound on the A-weighted sound-level scale.

Source: Modified from DIRS 103233-DOE (1999, p. 3-39)

TYPICAL A-WEIGHTED SOUND LEVELS

	DECIBELS	
	140	
50-horsepower siren (33 meters)[a]		
	130	
Jet takeoff (66 meters)		
	120	Diesel motors
Riveting machine[b]		
	110	
Cut-off saw Pneumatic peen hammer[b]		
	100	Outdoor public address system loudspeakers
Rock drill (16 meters) Textile weaving plant[b] Subway train (6.6 meters) Dump truck (16 meters) Pneumatic drill (16 meters)	90	Ventilation fans
	80	
Freight train (33 meters) Vacuum cleaner (3.3 meters) Speech (0.33 meters) Passenger auto (16 meters)	70	Inside sports car (24 meters per second)[c]
Large transformer (66 meters)	60	Near freeway (auto traffic) Large store Accounting office
	50	Private business office Light traffic (33 meters) Average residence
	40	
Soft whisper (13 centimeters)[d]		
	30	Studio (speech)
	20	Quiet
	10	
Threshold of hearing (youths)	0	

a. To convert meters to feet, multiply by 3.2808.
b. Operator's position.
c. 24 meters per second = about 50 miles per hour.
d. 13 centimeters = about 5 inches.

3.1.10 AESTHETICS

Visual resources, with nighttime darkness as a component, include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The physical features representing the region of influence for aesthetics are those found within the approximate boundary of the analyzed land withdrawal area. Sections 3.1.3 and 3.1.5 describe the geologic and biological settings, respectively, at Yucca Mountain.

The region surrounding Yucca Mountain consists of unpopulated to sparsely populated desert and rural lands. Because much of Yucca Mountain is on the Nevada Test Site and Nellis Air Force Range with restricted public access, public visibility is limited to portions of U.S. Highway 95 near Amargosa Valley.

Table 3-33. Benchmark ground vibration criteria for buildings and human annoyance.[a]

Category	Frequent events (>70/day) VdB[b]	Infrequent events (<70/day) PPV (in/sec)[c]	Infrequent events (<70/day) VdB	Impact of concern
Annoyance or interference				
1. High sensitive buildings[d]	65	NA[e]	65	Sensitive equipment
2. Residential[f]	72	NA	80	Human disturbance
3. Institutional[g]	75	NA	83	Human disturbance
Structural damage				
Fragile buildings	NA	0.20	~100 (Impulse) 92 (Rail)	Structural damage
Extremely fragile buildings	NA	0.12	~95 (Impulse 88 (Rail)	Structural damage

a. Source: DIRS 155547-HMHH (1995, p. 8-3).
b. Root-mean-square velocity expressed in decibels - VdB - referenced to 10^{-6} inch per second.
c. Peak particle velocity in inches per second; to convert to millimeters per second, multiply by 25.4.
d. Buildings with vibration-sensitive equipment (for example, at research institutions and medical facilities).
e. NA = not applicable.
f. Homes or buildings where people sleep.
g. Schools, churches, and office buildings.

The Bureau of Land Management uses four visual resource classes in the management of public lands (DIRS 101505-BLM 1986, all). Classes I and II are the most valued, Class III is moderately valued, and Class IV is of least value. Visual resources fall into one of these management classes based on a combination of three factors: (1) scenic quality, (2) visual sensitivity, and (3) distance from travel routes or observation points (DIRS 101505-BLM 1986, all). There are three scenic quality classes in the Bureau of Land Management Visual Resource Management system. Class A includes areas that combine the most outstanding characteristics of each physical feature category. Class B includes areas in which there is a combination of some outstanding and some fairly common characteristics. Class C includes areas in which the characteristics are fairly common to the region. A visual sensitivity rating for an area is based on the number and types of users, special areas (natural areas, wilderness areas), public interest in the area, and adjacent land uses. Though a scenic quality rating (A, B, or C) is used in conjunction with visual sensitivity and distance zones (foreground, middleground, background, and seldom seen) to produce Visual Resource Management Classes, the scenic quality rating is often used independently to emphasize a visual resource within a management class area. For example, a Wilderness Study Area might have a Class A scenic rating and be in a Class II or III management area.

The Bureau of Land Management has not assigned a Visual Resource Management class to Yucca Mountain because the Nevada Test Site is not under the Bureau's jurisdiction. However, using the Bureau's method of determining scenic quality, DOE has evaluated the visual resources of the Yucca Mountain region from two observation points—one at Amargosa Valley on U.S. 95 and the other on the Nevada Test Site at a location that provides a clear view of the proposed repository site (DIRS 105002-CRWMS M&O 1999, all).

The visual assessment at both these locations concluded that the scenic quality classification of Yucca Mountain is C.

Nighttime darkness in the Yucca Mountain region is a valued component of the solitude experience sought by many individuals, and greatly enhances astronomy and stargazing activities. It is also felt to be one of the important scenic resources of the Death Valley National Park. Existing or potential sources of nighttime light in this area include the Towns of Beatty and Amargosa Valley that lie between Death Valley National Park and the Yucca Mountain site; the community of Pahrump slightly east of the Park; and Las Vegas farther to the east. Las Vegas is the largest source of nighttime light in the extended region; the glow of its lights is evident in the night sky at much farther distances than other city features.

BUREAU OF LAND MANAGEMENT VISUAL RESOURCE MANAGEMENT CLASS OBJECTIVES (used in the management of public lands)

Class I	The objective of this class is to preserve the existing character of the landscape. This class provides for natural ecological changes; however, it does not preclude very limited management activity. The level of change to the characteristic landscape should be very low and must not attract attention.
Class II	The objective of this class is to retain the existing character of the landscape. The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.
Class III	The objective of this class is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape.
Class IV	The objective of this class is to provide for management activities that require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high. These management activities may dominate the view and be the major focus of viewer attention. However, every attempt should be made to minimize the impact of these activities through careful location, minimal disturbance, and repeating the basic elements.

Current lighting at the repository site is similar to or less than lighting at other work areas on the Nevada Test Site and represents a minor contribution to the area's sources of nighttime lighting.

3.1.11 UTILITIES, ENERGY, AND SITE SERVICES

DOE research into the current consumer demand for utilities and energy in the Yucca Mountain region has yielded information on water and power sources, use, and supply systems. The research included water treatment capabilities. The region of influence for potential impacts to utility and energy supplies consists of those public and private resources on which DOE would draw to support the Proposed Action, and which are in Clark, Lincoln, and Nye Counties in Nevada. Sections 3.1.11.1 and 3.1.11.2 contain information on current water and energy suppliers and consumer use. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Utilities, Energy, and Site Services* (DIRS 104988-CRWMS M&O 1999, all) is the basis of the information in this section.

3.1.11.1 Utilities

Water and sewer utilities in the region could be affected by the Proposed Action as a result of project-related increases in population and the associated increases in water demand and sewage production. DOE anticipates that the predominant project-related increase in population would occur in Clark County, with a smaller increase in Nye County (see Section 3.1.7).

Water. The Southern Nevada Water Authority supplies water to five communities in Clark County: Boulder City, Henderson, Las Vegas (including parts of unincorporated Clark County), Nellis Air Force

Base, and North Las Vegas. Eighty-five percent of the water supplied to the Las Vegas Valley comes from the Colorado River through Lake Mead; the remaining 15 percent comes from groundwater (Las Vegas Valley Hydrographic Area; DIRS 101923-SNWA 1997, p. 2). To meet growing water demands, the Water Authority is upgrading current facilities and installing new facilities, such as a second raw water intake at Lake Mead, a second water treatment facility, and additional pipelines and pumping stations.

In southern Nye County, where the repository would be, groundwater is the only source of water. In August 1996, a water supply and demand evaluation for southern Nye County, including Beatty, Amargosa Desert, and Pahrump, was performed (DIRS 101542-Buqo 1996, all). The evaluation indicated the Beatty (Oasis Valley Hydrographic Area) water utility would have difficulty meeting future water demands due not to a high growth rate but to falling well yields and poor water quality in some wells. It further predicted that existing pumping capacity would not be adequate to meet projected peak demands between 1997 and 2000, and one or more additional wells would be needed. Since the 1996 evaluation, Beatty has gained the use of another well (formerly used by the Bullfrog Mine), which has provided a capacity sufficient to meet water demand now and for the immediate future, even while ending the use of two wells with high fluoride (DIRS 156759-Davis 2001, all). In Amargosa Desert (Amargosa Desert Hydrographic Area), the current committed amount of groundwater appropriations (permits and certificates) is larger than the lower estimate of perennial yield for the applicable groundwater. However, historic pumping amounts have never been higher than the estimates of yield. In Pahrump (Pahrump Valley Hydrographic Area), the total groundwater pumped from the basin in 1995 was almost 30 million cubic meters (24,000 acre-feet). This is about 25 percent higher than the upper end of estimates of the basin's perennial yield, which range from 15 million cubic meters [12,000 acre-feet (DIRS 103406-NDWP 1992, Region 10)] to 23 million cubic meters [19,000 acre-feet (DIRS 101542-Buqo 1996, p. 17)]. Much of Pahrump's water consumption results from about 7,000 domestic water supply wells. Drilling continues at a rate of about 700 wells a year (DIRS 103099-Buqo 1999, p. 36) . Alternatives to address long-term water supply issues in Pahrump Valley include optimizing the locations of new wells, reducing per capita consumption, developing the carbonate aquifer, and importing water from other groundwater basins. Overall groundwater withdrawals in Nye County totaled about 93 million cubic meters (75,000 acre-feet) in 1995. The predominant use of this water was agriculture, accounting for 80 percent of the total; domestic use was responsible for only 7 percent of the total withdrawal (DIRS 104888-LeStrange 1997, Table 1).

Sewer. Wastewater treatment needs in the Las Vegas Valley are supported by three major wastewater treatment facilities: one operated by the City of Las Vegas (which also serves the City of North Las Vegas); one operated by the City of Henderson; and one operated by the Clark County Sanitation District. The County Sanitation District includes all the unincorporated areas in Clark County, and it provides services to several outlying communities including Blue Diamond, Laughlin, Overton, and Searchlight (DIRS 148106-Clark County Sanitation District 1999, all). However, its primary service area is the portion of the Las Vegas Valley south and east of the City of Las Vegas and extending to Henderson. There might be other small wastewater treatment units serving parts of Clark County outside the populous area of the Las Vegas Valley, but septic tank and drainage field systems provide the primary means of wastewater treatment in these outlying areas, particularly for private residences.

Southern Nye County does not have a metropolitan area or a sanitation district comparable to Clark County. Most communities in this area rely primarily on individual dwelling or small communal wastewater treatment systems, with the exception of Beatty, which has municipal sewer service. For example, Pahrump has no community-wide wastewater treatment system. Several wastewater treatment units serve parts of the town, such as the dairy and the jail, but most households have septic tank and drainage field systems. This is likely to be typical of the small communities in southern Nye County.

3.1.11.2 Energy

Electric Power. Three different power distributors—Nevada Power Company, Valley Electric Association, Inc., and Lincoln County Power District No. 1—supply electric power in the region of influence.

Nevada Power Company supplies electricity to southern Nevada in a corridor from southern Clark County, including Las Vegas, North Las Vegas, Henderson, and Laughlin, to the Nevada Test Site in Nye County. In 2000, the power sources were about 50 percent company-generated and about 50 percent purchased power. In 2000, Nevada Power Company sold 17.9 million megawatt-hours to its 620,000 customers, and the peak load was the highest ever at about 4,300 megawatts. Nevada Power Company has an annual customer growth rate of about 6 percent. To keep pace with demands for electricity, each year Nevada Power must build more substations and transmission and distribution facilities; in 2001 to 2003, it plans to invest about $320 million in such equipment (DIRS 155864-NPC 2000, all). Recent energy concerns have caused the forecasting of supply and demand to be much more uncertain than in the past, as reflected in recent planning documents released by Nevada Power Company. Nevada Power Company merged with Sierra Pacific Resources in July 1999 (DIRS 153929-NPC 1999, all). Sierra Pacific Resources is the holding company for the Sierra Pacific Power Company, which provides electric power to much of northern Nevada and the Lake Tahoe area.

The Valley Electric Association is a nonprofit cooperative that distributes power to southern Nye County, including Pahrump Valley, Amargosa Valley, Beatty, and the Nevada Test Site. The Western Area Power Administration allocates Valley Electric a portion of the lower cost hydroelectric power from the Colorado River dams. The private power market supplies the supplemental power necessary to meet the needs of the members. Since 1995, the amount of power available in the marketplace has been abundant. The amount of energy that Valley Electric sells annually to its members almost tripled in the 11 years from 1985 through 1995. In 1995, Valley Electric sold about 300 million kilowatt-hours to its 8,600 members (DIRS 101846-McCauley 1997, pp. 54 and 55). To meet the power demands of its members, Valley Electric has built a new 230-kilovolt transmission line from Las Vegas to Pahrump and plans to install three new substations in Pahrump.

At present, two commercial utility companies own transmission lines that supply electricity to the Nevada Test Site (Figure 3-26). The electric power for the Yucca Mountain Project in Area 25 comes through the Nevada Test Site power grid. The Test Site buys power at 138 kilovolts at the Mercury Switch Station and at the Jackass Flats Substation. The 138-kilovolt system at the Test Site has nine substations, one switching center, and one tap station, which are connected by approximately 210 kilometers (130 miles) of transmission line. A 138-kilovolt line owned by Nevada Power Company connects the Mercury Switch Station to the Jackass Flats substation, which reduces the power and transmits it to the Field Operations Center and nearby buildings in Area 25 that support the Yucca Mountain Project. A Valley Electric Association 138-kilovolt line also provides power to the Jackass Flats Substation. From the Jackass Flats substation, a 138-kilovolt line feeds the Canyon Substation in Area 25, which provides power to the Exploratory Studies Facility. The Canyon Substation reduces the voltage from 138 to 69 kilovolts, with a capacity of 10 megawatts, and transmits it to the Yucca Mountain substation at the Exploratory Studies Facility.

The capacity of the Nevada Test Site grid is 72 megawatts. Since 1990, the peak load was about 37 megawatts and occurred in January 1992 (DIRS 104955-LeStrange 1997, p. 1).

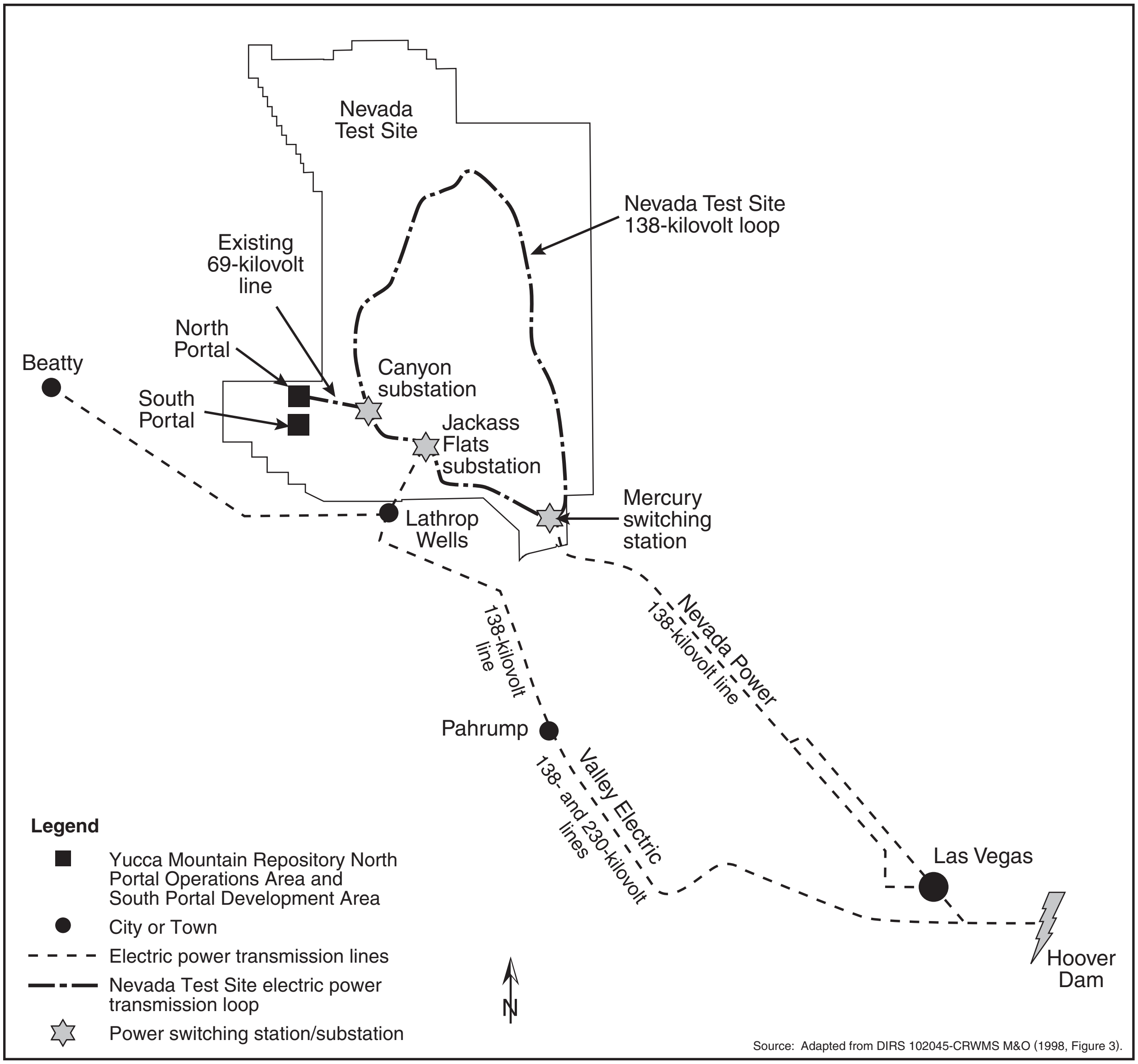

Figure 3-26. Existing Nevada Test Site electric power supply.

Table 3-34 lists the combined historic and projected electricity use for the Exploratory Studies Facility and the Field Operations Center for 1995 through 2000. The Exploratory Studies Facility consumed about 70 percent of the listed amounts (DIRS 104955-LeStrange 1997, all). Annual power use and peak demand at the Exploratory Studies Facility would probably decline and stabilize at a lower level than the 1997 use rates because site activity would decline until repository construction began in 2005. Historically, from 1995 through 1997 Exploratory Studies Facility use has accounted for about 15 percent to 20 percent of the electric power used by all of the Nevada Test Site (DIRS 104988-CRWMS M&O 1999, Table 2, p. 6).

Fossil Fuel. The fossil fuels that DOE has used at the Exploratory Studies Facility are heating oil, propane, diesel, gasoline, and kerosene. Natural gas, coal, and jet fuel have not been used. In 1996, site activities consumed about 1.02 million liters (270,000 gallons) of heating oil and diesel fuel and about 65,000 liters (17,000 gallons) of propane; in 1997, they consumed slightly less than 1 million liters (264,000 gallons) of heating oil and diesel fuels. The amounts of gasoline and kerosene used at the

Table 3-34. Electric power use for the Exploratory Studies Facility and Field Operations Center.[a,b]

Fiscal Year	Power use: Consumption (megawatt-hours)	Power use: Peak (megawatts)
1995	9,800	3.5
1996	19,000	4.9
1997	23,000	5.3
1998[c]	21,000	4.2
1999[c]	17,000	4.2
2000[c]	8,700	4.2

a. Source: DIRS 104988-CRWMS M&O (1999, Table 2, p. 6)
b. Before 1995, Yucca Mountain Project power was not metered separately.
c. Estimated.

Exploratory Studies Facility were very small in those years. Fossil-fuel supplies are delivered to the Nevada Test Site and the Exploratory Studies Facility by truck from readily available supplies in southern Nevada.

3.1.11.3 Site Services

DOE has established an existing support infrastructure to provide emergency services to the Exploratory Studies Facility. The Yucca Mountain Project *Emergency Management Plan* (DIRS 102618-YMP 1998, all) describes emergency planning, preparedness, and response. The project cooperates with the Nevada Test Site in such areas as training and emergency drills and exercises to provide full emergency preparedness capability to the site. In addition, the project trains and maintains an underground rescue team. The Nevada Test Site security program is responsible for project security, with enforcement provided by a contractor following direction from DOE. The Nye County Sheriff's Department provides law enforcement and officers for Yucca Mountain site patrol. Nevada Test Site personnel and equipment support fire protection and medical services. Medical services are provided through the Nevada Test Site by two paramedics and an ambulance stationed in Area 25 with backup from other Test Site locations. The Yucca Mountain staff uses a medical clinic with outpatient capability at Mercury. Urgent medical transport is provided by the "Flight for Life" and "Air Life" programs from Las Vegas. Nellis Air Force Base and Nye County also provide emergency support.

3.1.12 WASTE AND HAZARDOUS MATERIALS

The region of influence for waste and hazardous materials consists of on- and offsite areas, including landfills and radioactive waste processing and disposal sites, in which DOE would dispose of waste generated under the Proposed Action. This region of influence can be described, to a large extent, through considering the manner in which waste has been managed during the current Yucca Mountain activities.

The Yucca Mountain Site Characterization Project developed its waste management systems to handle the waste and recyclable material generated by its activities. This material includes nonhazardous solid waste; construction debris; hazardous waste; recyclables such as lead-acid batteries, used oil, metals, paper, and cardboard (DIRS 152012-McCann 2000, pp. 1 to 6); sanitary sewage; and wastewater. It does not include low-level radioactive or mixed wastes. DOE uses landfills to dispose of solid waste and construction debris; accumulates and consolidates hazardous waste, then transports it off the site for treatment and disposal; treats and reuses wastewater; and treats and disposes of *sanitary waste*. In most categories of waste, especially solid waste, some types of material can be recycled or reused. DOE has processes in place to ensure that it collects the material and recycles it as appropriate.

3.1.12.1 Solid Waste

DOE disposes of Yucca Mountain Site Characterization Project solid waste and construction debris in landfills in Areas 23 and 9, respectively, on the Nevada Test Site. The Area 23 landfill has a capacity of 450,000 cubic meters (16 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37) and a 100-year estimated life (DIRS 101803-DOE 1995, p. 9). The Area 9 landfill, which is in Crater U-10C, is an open circular pit with steep, almost vertical sides formed as a result of an underground nuclear test. The Area 9 landfill has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37) and an estimated 70-year operational life (DIRS 101803-DOE 1995, p. 8). The environmental impact statement for the Nevada Test Site describes these landfills (DIRS 101811-DOE 1996, p. 4-37). DOE disposes of Yucca Mountain Site Characterization Project oil-contaminated debris from maintenance activities at the industrial landfill at Apex, Nevada, using an environmental company for transport and disposal. The Apex facility is a multilined landfill with on- and offsite monitoring in compliance with State of Nevada requirements (DIRS 152012-McCann 2000, p. 3).

DOE recycles as many materials as feasible from its site characterization activities. The *Waste Minimization and Pollution Prevention Awareness Plan, Approved* (DIRS 103203-YMP 1997, all) governs recycling and other waste minimization activities. At present, a Nevada Test Site contractor collects paper, cardboard, aluminum cans, and scrap metal and recycles it. For such recyclables as oils, solvents, coolants, lead-acid batteries, and oil-contaminated soils, the Yucca Mountain Site Characterization Project contracts directly with recycling services (DIRS 152012-McCann 2000, pp. 1 to 5).

Solid waste generated by the construction and operation of transportation facilities could be disposed of in offsite landfills. At present, there are 24 operating municipal solid waste landfills in Nevada (DIRS 155563-NDEP 2001, all) with a combined capacity to accept 11,000 metric tons (12,000 tons) of waste per day. In 2000, about 3.5 million metric tons (3.9 million tons) of sanitary solid waste was disposed of in Nevada (DIRS 155565-NDEP 2001, Section 2.1). Eleven Nevada landfills accept industrial and special waste (DIRS 155563-NDEP 2001, all), which includes construction debris and other solid waste such as tires that have specific management requirements for permitted landfill disposal. The State's largest regional landfill accepts municipal and industrial waste and has a capacity of 6,300 metric tons (6,900 tons) per day (DIRS 155563-NDEP 2001, all). In 2000, about 750,000 metric tons (823,000 tons) of construction debris and about 83,000 metric tons (91,000 tons) of other wastes were disposed of in the State (DIRS 155565-NDEP 2001, Section 2.1).

3.1.12.2 Hazardous Waste

The Yucca Mountain Site Characterization Project is a small-quantity [less than 1,000 kilograms (2,200 pounds) a month] generator of hazardous waste. DOE accumulates hazardous wastes near their generation sources, consolidates them at a central location at the Yucca Mountain site, and ships them off the site for treatment and disposal. The hazardous waste accumulation areas are managed in accordance with Federal and State regulations. The waste is treated and disposed of off the site at a permitted treatment, storage, and disposal facility (DIRS 152012-McCann 2000, p. 6).

3.1.12.3 Wastewater

DOE uses a septic system to treat and dispose of sanitary sewage at the Yucca Mountain site (DIRS 102303-CRWMS M&O 1998, p. 15). The system design can handle a daily flow of about 76,000 liters (20,000 gallons) (DIRS 102599-CRWMS M&O 1998, p. 64).

At present, wastewater from tunneling operations and water from secondary containment (following rains) is processed through an oil-water separator, and the treated water is used for dust suppression in accordance with a State of Nevada permit (DIRS 152012-McCann 2000, p. 4). The oil is recycled with the other used oil generated by the project.

3.1.12.4 Existing Low-Level Radioactive Waste Disposal Capacity

The Nevada Test Site accepts low-level radioactive waste for disposal from approved generator sites. It has an estimated disposal capacity of 3.7 million cubic meters (130 million cubic feet). DOE estimates that a total of approximately 1.1 million cubic meters (39 million cubic feet) of low-level radioactive waste will be disposed of at the Test Site through 2070 (DIRS 155856-DOE 2000, Table 4-1, p. 4-2), not including repository-generated waste.

Commercial spent nuclear fuel generators and contractor-operated transportation facilities such as an intermodal transfer station would dispose of low-level radioactive waste in commercial facilities. Commercial disposal capacity for low-level radioactive wastes is available at three licensed facilities (DIRS 152583-NRC 2000, U.S. Low-Level Radioactive Waste Disposal Section).

3.1.12.5 Materials Management

DOE has programs and procedures in place to procure and manage hazardous and nonhazardous chemicals and materials (DIRS 104842-YMP 1996, all). By using these programs, the Department is able to minimize the number and quantities of hazardous chemicals and materials stored at the Yucca Mountain site and maintain appropriate storage facilities.

The chemical and material inventory report (DIRS 148107-Dixon 1999, pp. 4, 4a, and 5) for the Nevada State Fire Marshal's office lists 33 hazardous chemicals and materials. The Yucca Mountain Project holds many of these in small quantities, and it stores sulfuric acid in larger quantities [above the threshold planning quantity of about 450 kilograms (1,000 pounds) that requires emergency planning]. Most of the sulfuric acid is in lead-acid batteries (DIRS 148107-Dixon 1999, all). In addition, the Yucca Mountain Site Characterization Project stores the following hazardous chemicals in large amounts [exceeding 4,500 kilograms (10,000 pounds)]: propane, gasoline, cement, and lubricating and hydraulic oils. The project does not store highly toxic substances in quantities higher than the State of Nevada reporting thresholds (DIRS 148107-Dixon 1999, p. 1).

3.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs each Federal agency "to make achieving environmental justice a part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations."

DOE has identified the minority and low-income communities in the Yucca Mountain region of influence, which consists of Clark, Lincoln, and Nye Counties in southern Nevada. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (DIRS 105004-CRWMS M&O 1999, all) is the basis for information in this section.

ENVIRONMENTAL JUSTICE TERMS

Minority: Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other non-white person.

Low income: Below the poverty level as defined by the Bureau of the Census.

To identify minority and low-income communities in the region of influence, DOE analyzed Bureau of the Census population designations called *block groups*. DOE pinpointed block groups where the percentage of minority or low-income residents is meaningfully greater than average. For environmental justice purposes, the pinpointed block groups are minority or low-income communities. This EIS considers whether activities at Yucca Mountain could cause disproportionately high and adverse human health or environmental effects to those communities.

3.1.13.1 State of Nevada

Minority persons comprised 21 percent of the population in Nevada in the 1990 census (DIRS 103118-Bureau of the Census 1992, Table P8; DIRS 103119-Bureau of the Census 1992, Table P12). In the 2000 Census, minority persons comprised 35 percent of the population of Nevada (DIRS 156909-Bureau of the Census 2001, p. 1 of Table DP-1; Nevada). It should be noted, however, that between the 1990 Census and the 2000 Census, changes in the Bureau of the Census definitions modified previous race and ethnic categories and for the first time permitted citizens to identify themselves as belonging to more than one category. The Bureau's *Overview of Race and Hispanic Origin*, a Census 2000 Brief issued in March 2001, stated (DIRS 157135-Bureau of the Census 2001, all):

> *Because of these changes, the Census 2000 data on race are not directly comparable with data from the 1990 census or earlier censuses. Caution must be used when interpreting changes in racial composition of the U.S. population over time.*

The environmental justice analysis considered the potential for disproportionately high and adverse impacts on two portions of the overall population—minority communities and low-income communities. While 2000 Census data concerning minority communities in Nevada was available at the block level in time for the Final EIS analysis, comparable 2000 Census data on low-income communities was not. The Final EIS presents 2000 Census data at the block level on minority communities and 1990 Census data at the block group level on low-income communities. This data is the most up-to-date information available for each.

As a consistent criterion for identifying minority and low-income blocks and block groups, DOE employed a 10-percent threshold, meaning that the environmental analysis focused on blocks and block groups in Nevada having a 10-percent or greater minority population or low-income population than the State averages. DOE adopted the 10-percent threshold for the Draft EIS from a 1995 Nuclear Regulatory Commission document, *Interim NRR Procedure for Environmental Justice Reviews* (DIRS 103426-NRC 1995, all). This threshold is consistent with the recent revision of the Nuclear Regulatory Commission's guidance on environmental justice (DIRS 157276-NRC 1999, all).

The environmental justice analysis identified minority communities at the Bureau of the Census block level and low-income communities at the Bureau of the Census block group level. Figure 3-27 shows blocks in the State of Nevada in which 45 percent or more of the population consists of minority persons, according to the 2000 Census. The difference between block level and block group level can be seen in comparing Figure 3-27 to Figure 3-28, which identifies low-income communities at the block group level. The block is a finer resolution; the block group presents the criterion over an aggregate of blocks. Both types of data sets have advantages over the other, depending on the specific analysis being performed. Census blocks can be quite large in rural areas where population density is low because they are associated with a relatively small number of persons. In populous areas such as Las Vegas, the block size is usually quite small and is not clearly depicted on a scale such as that shown in Figure 3-27. Figure 3-29 shows blocks in the Las Vegas area with 45 percent or higher minority population.

The 1990 census characterized about 10 percent of the people in Nevada as living in poverty (DIRS 103120-Bureau of the Census 1992, Table P117). The Bureau of the Census characterizes persons in poverty as those whose income is less than a statistical poverty threshold, which is based on family size and the ages of its members. In the 1990 census the threshold for a family of four was a 1989 income of $12,674 (DIRS 102119-Bureau of the Census 1995, Section 14). In this environmental impact statement, low-income communities are those block groups in which the percentage of persons in poverty equals or exceeds 20 percent as reported by the Bureau of the Census. Figure 3-28 shows low-income communities in Nevada by block group. Figure 3-30 shows low-income communities in the Las Vegas area by block group.

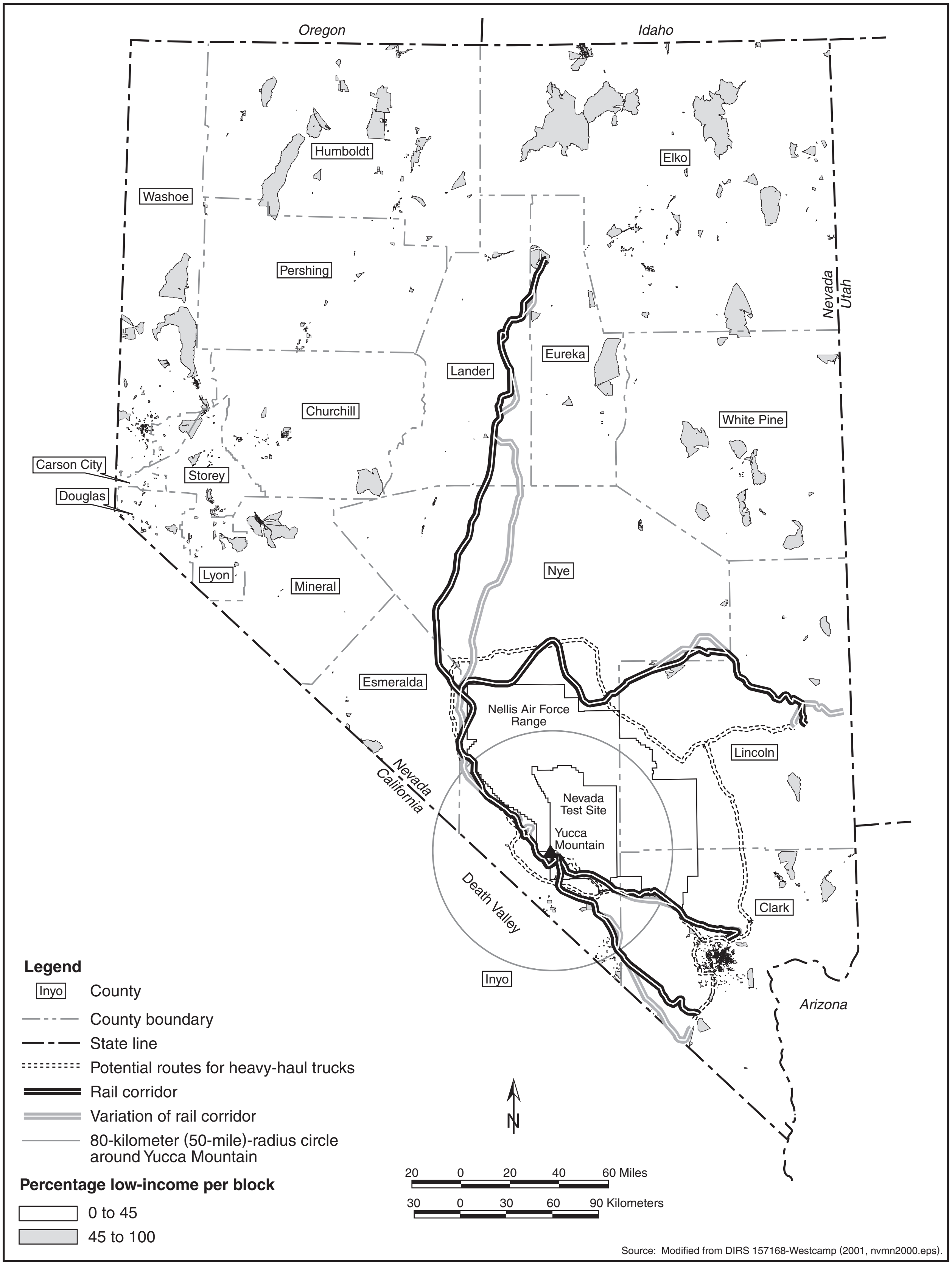

Figure 3-27. Minority communities in Nevada.

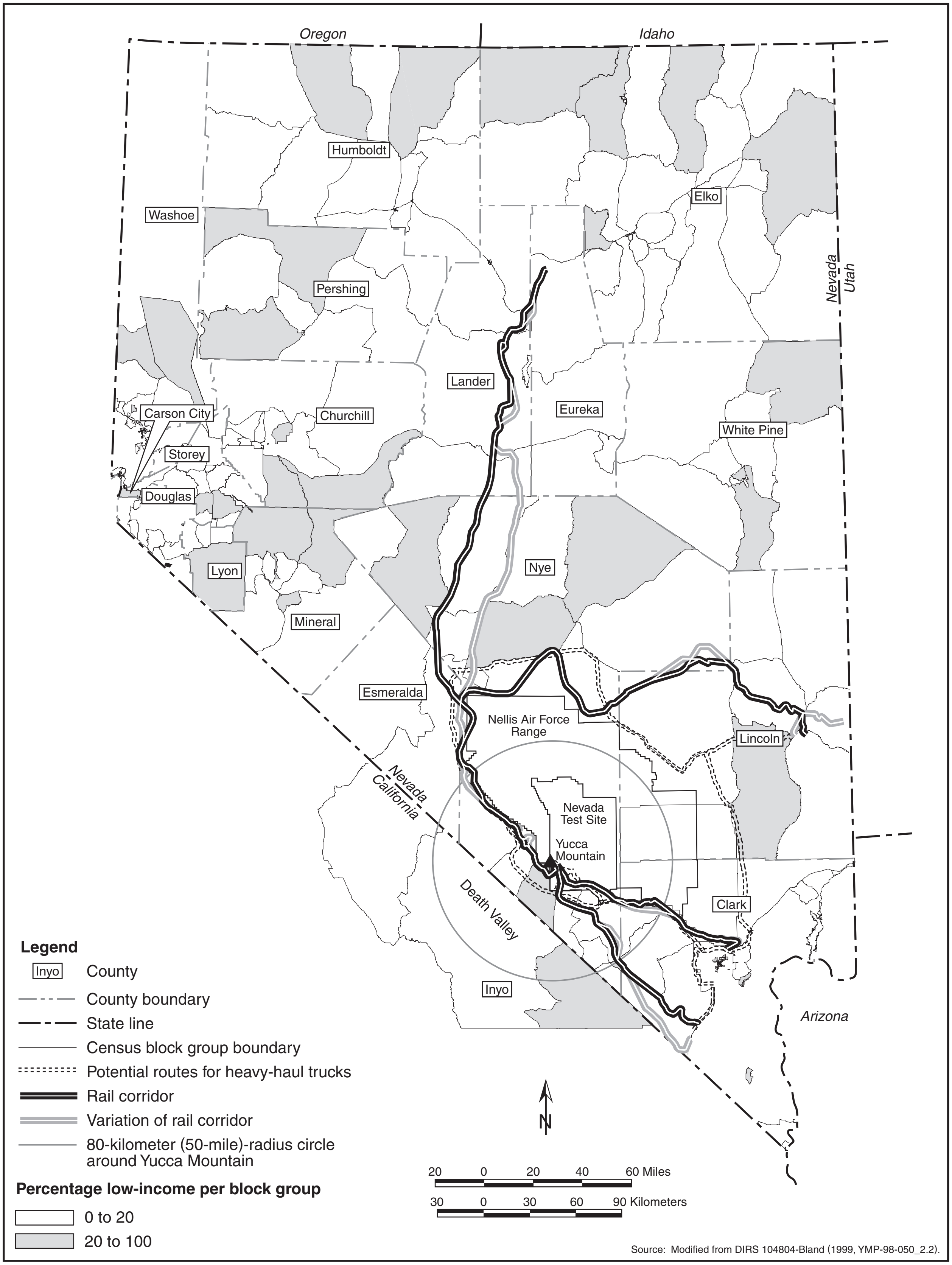

Figure 3-28. Low-income communities in Nevada.

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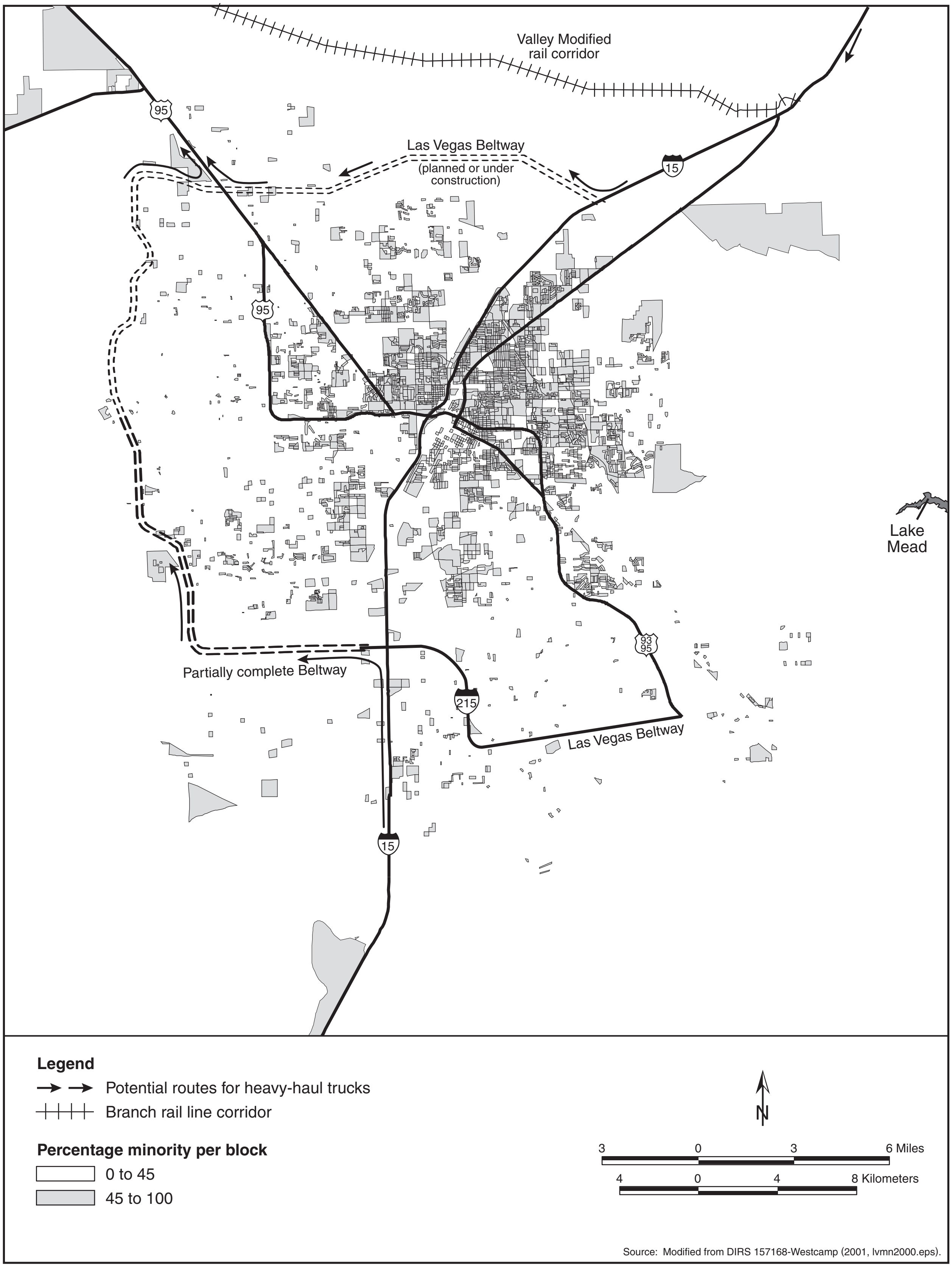

Figure 3-29. Minority census blocks in the Las Vegas metropolitan area.

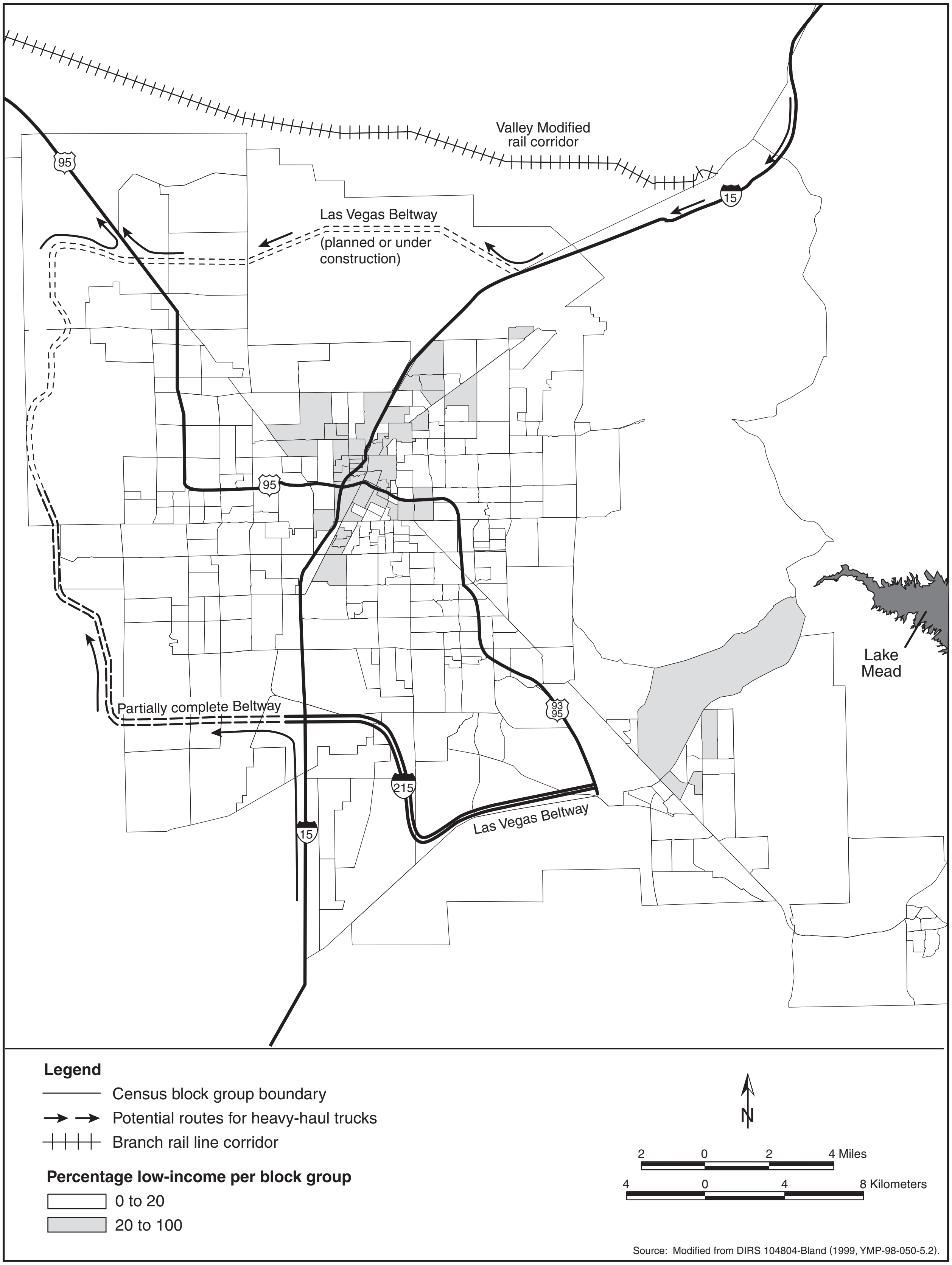

Figure 3-30. Low-income census block groups in the Las Vegas metropolitan area.

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3.1.13.2 Clark County

In 2000, the minority population of Clark County was about 548,000 persons, or 40 percent of the *total population* (DIRS 156909-Bureau of the Census 2001, p. 3 of Table DP-1; Clark County). In 1990, a total of about 80,000 residents, or 11 percent of the Clark County population, was characterized as living in poverty (DIRS 103123-Bureau of the Census 1992, Table P117).

3.1.13.3 Lincoln County

In 2000, the Lincoln County minority population consisted of about 450 persons, or 10 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 10 of Table DP-1; Lincoln County). In 1990, 500 persons, or 14 percent of the population, were characterized as living in poverty (DIRS 103127-Bureau of the Census 1992, Table P117).

3.1.13.4 Nye County

In 2000, the Nye County minority population was about 5,000 persons, or 15 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 13 of Table DP-1; Nye County). In 1990, there were 2,000 persons, or 11 percent of the population, characterized as living in poverty (DIRS 103131-Bureau of the Census 1992, Table P117).

3.1.13.5 Inyo County, California

One block group with a low-income population located in the area of the Stewart Valley in Inyo County, California, lies partly within the 80-kilometer (50-mile) air quality region of influence for the repository (Figure 3-25). DOE performed additional review, including a ground survey, and concluded that low-income persons living in the block group would be likely to live outside the 80-kilometer region of influence for the repository.

3.2 Affected Environment Related to Transportation

This section describes the existing (or baseline) environmental conditions along the candidate rail corridors and truck (legal-weight and heavy-haul) routes to the Yucca Mountain site. The EIS treats these corridors and routes as current analytical tools and refers to them in the present tense. The EIS refers to impacts associated with these alternatives in the conditional voice (would) because they would not occur unless DOE proceeded with the Proposed Action. This convention is applied whenever the EIS discusses the transportation implementing alternatives.

DOE has made revisions to this section since the publication of the Draft EIS to present newly acquired information that contributes to an improved (or updated) understanding of the potentially affected environment, to address more specifically the affected environment along the rail corridor variations in Nevada, and to include information and suggestions for improvement provided through public comment on the Draft EIS and the Supplement to the Draft EIS. The more significant changes occur in the Nevada Transportation section (Section 3.2.2) and particularly in the discussion of candidate rail corridors (Section 3.2.2.1). Key changes to the Final EIS that deal with affected environment for transportation are summarized in the following:

- Incorporated updates to the land use discussions based on actions since the Draft EIS, including land transfers to the Timbisha Shoshone Tribe for establishment of new reservation; and to Clark County for the development of the Ivanpah Valley Airport and the Apex Industrial Park.

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- Improved descriptions of land use and aesthetics as a result of the collection of additional information, including perspectives gained from a ground survey of the potential rail corridors.

- Expanded hydrology discussions, primarily by reference to Appendix L, to include results of an effort to compile information on 100-year flood zones along the rail corridors and their variations.

- Augmented the biological resources discussion for potential Nevada rail corridors to biological resources and soils by adding a new soils section to describe several pertinent soil characteristics and their presence along the rail corridors and their variations.

- Expanded cultural resources discussions to incorporate results of an effort to collect and evaluate additional baseline data for the Nevada Transportation for the rail corridors and the heavy-haul truck routes.

- Updated baseline socioeconomic data to incorporate information from the 2000 Census and, as appropriate, information from the State Demographer and local government agencies.

- Expanded the noise discussion to address background levels of ground vibration along both the rail corridors and the heavy-haul truck routes.

- Updated and refined the environmental justice methodology described for candidate rail corridors, including the incorporation of more detailed maps (in Appendix J) of minority populations.

- Expanded information presented in the land use, hydrology (surface-water and groundwater), biological resources, and cultural resources discussions to address more specifically applicable variations to each of the rail corridors.

3.2.1 NATIONAL TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would occur at 72 commercial and 5 DOE sites in 37 states. Transport of these materials to the Yucca Mountain site could involve trains, legal-weight trucks, heavy-haul trucks, and barges; the trains and trucks would travel on the Nation's railroads and highways. This includes existing railroads and highways in Nevada up to a point of departure to specific Nevada routes described in Section 3.2.2. Barges and heavy-haul trucks would be used for short-distance transport of spent nuclear fuel from storage sites to nearby railheads. (Heavy-haul trucks could also be used for Nevada transportation, as discussed in Section 3.2.2.2.)

The national transportation of spent nuclear fuel and high-level radioactive waste (including transportation in Nevada to a point of departure to a specific Nevada transportation route) would use existing highways and railroads and would represent a small fraction of the existing national highway and railroad traffic [less than 1 percent (0.006 percent) of truck miles per year or 0.007 percent of railcar miles per year (DIRS 150989-BTS 1998, p. 6)]. Because no new land acquisition and construction would be required to accommodate these shipments, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes.

The region of influence for public health and safety along existing transportation routes is 800 meters (0.5 mile) from the centerline of the transportation rights-of-way and from the boundary of railyards for incident-free (nonaccident) conditions. The region of influence extends to 80 kilometers (50 miles) to address potential human health and safety impacts from accident scenarios.

DOE used HIGHWAY (DIRS 104780-Johnson et al. 1993, all) and INTERLINE (DIRS 104781-Johnson et al. 1993, all) computer models to derive representative highway and rail routes, respectively, for shipping spent nuclear fuel and high-level radioactive waste. In addition to identifying routes that were used in the analysis, these models were used to estimate population densities along routes in states other than Nevada based on the 1990 Census. The HIGHWAY model identified highway routes between the commercial and DOE generator sites and the proposed repository that would meet the requirements of U.S. Department of Transportation regulations; there are no corresponding Federal regulations that constrain the routing of rail shipments. The analysis used population densities along the highway and rail routes to estimate human health impacts and consequences of transportation. Except in Nevada, the analysis accounted for growth in populations along routes by increasing impacts based on Bureau of the Census forecasts of state populations in 2025, population reported by the 2000 Census for each state, and extrapolation of population growth along routes to 2035. For routes in Nevada, DOE used a Geographic Information System and 1990 census data to develop an initial estimate of the populations within 800 meters (0.5 mile) along highways, commercial rail lines, and the potential corridors for a proposed branch rail line. The analysis of health and safety impacts accounted for growth in populations along Nevada routes by increasing impacts based on forecasts of population growth in Nevada counties using the REMI computer program. The analysis using the REMI program used population growth forecasts provided by Clark County, Nye County, and the State of Demographer and census data for each county provided by the 2000 Census to estimate populations in Nevada in 2035.

3.2.1.1 Highway Transportation

USE OF REPRESENTATIVE ROUTES IN IMPACT ANALYSIS

At this time, prior to approval of the site for development and operation of a repository and years prior to a possible first shipment, the actual routes that would be used to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain have not been identified. However, the highway and rail routes used for analysis in this EIS are representative of routes that could be used. The highway routes conform to U.S. Department of Transportation regulations (49 CFR 397.101). These regulations, developed for transportation of Highway Route Controlled Quantities of Radioactive Materials, require such shipments to use preferred routes that would reduce the time in transit. A preferred route is an Interstate System highway, bypass, or beltway, or an alternative route designated by a state routing agency. Alternative routes could be designated by states and tribes under U.S. Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with local jurisdictions and other states. Federal regulations do not restrict the routing of rail shipments. However, for the analysis, as discussed in Appendix J, Section J.1.1.3 of the EIS, DOE assumed routes for rail shipments that would provide expeditious travel, use of high quality track, and the minimum number of interchanges between railroads.

Highway (legal-weight truck) transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use local highways near the commercial and DOE sites and near Yucca Mountain, Interstate Highways, Interstate bypasses around metropolitan areas, and preferred routes designated by state routing agencies where applicable. DOE used the HIGHWAY computer program (DIRS 104780-Johnson et al. 1993, all) to derive representative highway routes for shipping spent nuclear fuel and high-level radioactive waste between the commercial and DOE sites and the proposed repository. Population density distributions, with the exception of those routes in Nevada, were calculated along the routes to support human health risk consequences. DOE used a Geographic Information System to calculate the population density distributions for routes in Nevada.

Appendix J describes the representative routes used for analysis in this EIS. Actual transportation mode and routing decisions would be made on a route-specific basis during the transportation planning process, if a decision was made to build a repository at Yucca Mountain.

3.2.1.2 Rail Transportation

In most cases, rail transportation of spent nuclear fuel and high-level radioactive waste would originate on track operated by shortline rail carriers that provide service to the commercial and DOE sites. At railyards near the sites, shipments in general freight service would switch from trains and tracks operated by the shortline rail carriers to trains and tracks operated by national mainline railroads. Figure 2-23 in Chapter 2 shows existing mainline track for the major U.S. railroads that DOE could use for shipments to Nevada. This interlocking network has about 290,000 kilometers (180,000 miles) of track that link the major population centers and industrial, agricultural, and energy and mineral resources of the Nation (DIRS 103069-AAR 1996, all). With the exception of shortline regional railroads that serve the commercial and DOE sites, DOE anticipates that cross-country shipments would move on mainline railroads.

Rail transportation routing of spent nuclear fuel and high-level radioactive waste shipments is not regulated by the U.S. Department of Transportation. The routes used in this EIS were derived from the INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all). The identification for purposes of analysis of these routes was based on current railroad practices using existing routes. Appendix J describes the rail routes used in this EIS analysis.

3.2.1.3 Barge and Heavy-Haul Truck Transportation

Commercial sites that do not have direct rail service could ship spent nuclear fuel on heavy-haul trucks or barges to nearby railheads. Heavy-haul trucks would use local highways to carry the spent nuclear fuel to a nearby railhead for transfer to railcars for transport to Nevada. Barge shipments would use navigable waterways accessible from the nuclear plant site. These shipments would travel on the waterways to nearby railheads for transfer to railcars for transport to Nevada. Appendix J describes the heavy-haul truck and barge routes used in this EIS analysis.

3.2.2 NEVADA TRANSPORTATION

Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would be transported to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. The discussion of national transportation modes and routes in Section 3.2.1 addresses the affected environment for legal-weight truck transport from commercial and DOE facilities to the Yucca Mountain site, including travel in Nevada. This section addresses the affected environment in Nevada for candidate rail corridors, heavy-haul truck routes, and potential locations for an intermodal transfer station that DOE could use for transporting spent nuclear fuel and high-level radioactive waste and that would require new construction.

Legal-weight truck shipments in Nevada would use existing highways and would be a very small fraction of the total traffic [less than 0.5 percent of commercial vehicle traffic on U.S. Highway 95 in southern Nevada (DIRS 103405-NDOT 1997, p. 9; DIRS 104727-Cerocke 1998, p. 1). Because no new land acquisition and construction would be required to accommodate legal-weight trucks, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes from legal-weight truck shipments. Appendix J contains baseline environmental information related to human health and safety and the impacts from accident scenarios.

To allow large-capacity rail cask shipments to the repository, DOE is considering the construction of a new branch rail line or the establishment of heavy-haul truck shipment capability. Sections 3.2.2.1 and 3.2.2.2 describe the existing (or baseline) environment for each of the candidate rail corridors and heavy-haul truck routes and for potential locations for an intermodal transfer station. The locations selected for candidate rail corridor starting points and for a potential intermodal transfer station are all accessible by main rail lines that are currently in operation. National rail transportation would simply involve routings to accommodate the selected starting point for Nevada transportation. DOE would prefer to use a branch rail line to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

3.2.2.1 Environmental Baseline for Potential Nevada Rail Corridors

This section discusses the environmental characteristics of land areas that could be affected by the construction and operation of a rail line to transport spent nuclear fuel and high-level radioactive waste to the proposed repository. It describes the environmental conditions in five alternative rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. Chapter 2, Section 2.1.3.2, describes these corridors in more detail. Figures 6-15 through 6-19 in Chapter 6 show detailed maps for these corridors.

To define the existing (or baseline) environment along the five proposed rail corridors; DOE has compiled environmental information for each of the following subject areas:

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.1.1)
- *Air quality and climate:* The quality of the air and the climate (Section 3.2.2.1.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.1.3)
- *Biological resources:* Important biological resources (Section 3.2.2.1.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.1.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.1.6)
- *Noise and vibration:* The existing noise environments (Section 3.2.2.1.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.1.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.1.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.1.10)

A Geographic Information System provided population distributions for differing population zones (urban, rural, suburban) along the candidate rail corridors. This approach, as discussed in Section 3.2.1, differs from the analysis for national transportation, which used the INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all) (see Chapter 6 for more detail).

DOE expects waste quantities generated by rail line construction and operation to be minor in comparison to those from repository construction and operation. As such, no discussion of existing waste disposal infrastructure along the routes is provided.

DOE evaluated the potential impacts of the implementing alternatives in regions of influence for each of the subject areas listed above. Table 3-35 defines these regions, which are specific to the subject areas, in which DOE could reasonably expect to predict potentially large impacts related to rail line construction and operation. The following sections describe the various environmental baselines for the rail implementing alternatives.

TERMS RELATED TO IMPLEMENTING ALTERNATIVE RAIL LINES

DOE has expanded the discussion of the affected environment in the corridors considered for rail use in this EIS. This includes the use of several terms that have specific meanings in the context of the discussion. In addition to this discussion, DOE has used these terms in the transportation analyses described in Chapter 6 and Appendix J. The following list defines these terms:

Implementing alternative **–** An action or proposition by DOE necessary to implement the Proposed Action and to enable the estimation of the range of reasonably foreseeable impacts of that action. In other words, an implementing alternative represents a feasible option that DOE could implement based in part on this EIS (for example, the selection of a branch rail line corridor).

The implementing rail alternatives for Nevada transportation are the five corridors—Carlin, Caliente, Caliente-Chalk Mountain, Jean, and Valley Modified—for a new branch rail line:

Corridor **–** A strip of land in Nevada, approximately 400 meters (0.25 mile) wide, that encompasses one of several possible routes through which DOE could build a rail line to transport spent nuclear fuel, high-level radioactive waste, and other material to and from the Yucca Mountain Repository site.

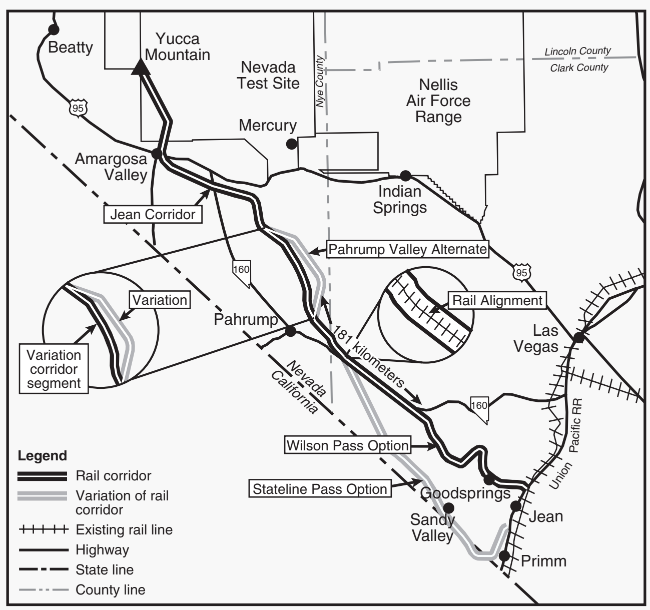
Alignment **–** The location of a rail line in a corridor. DOE has not determined the final alignment for a branch rail line in any of the candidate rail corridors.

Variation **–** In this context, a strip of land, approximately 400 meters (0.25 mile) wide, from one point along a corridor to another point on the same corridor that describes a different route. There are three types of variation:

Option **–** In this context, a variation based on a determination that the location of a corridor segment is essentially equivalent to that of another option, considering environmental and engineering factors.

Alternate **–** In this context, a variation in the location of a corridor segment to mitigate a potential adverse environmental or engineering factor.

Connection/Connector **–** In this context, a short variation of a corridor that connects a corridor to a commercial railroad or that connects an alternate or option of a corridor to the corridor.



DOE believes that this EIS provides the environmental impact information necessary to select a rail corridor. However, before DOE could select an alignment in that corridor, it would have to conduct additional field surveys; State, local, and tribal government consultations; engineering and environmental analyses; and National Environmental Policy Act reviews.

Table 3-35. Regions of influence for rail implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or whose ownership or use would change as a result of construction and use of branch rail line
Air quality and climate	The atmosphere in the vicinity of sources of criteria pollutants that would be emitted during branch rail line construction and operations, and particularly the Las Vegas Valley for implementing alternatives where constructing and operating a branch rail line could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards.
Hydrology	*Surface water:* areas near where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that could be affected by eroded soil or potential spills of construction contaminants
	Groundwater: aquifers that would underlie areas of construction and operations and aquifers that might be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands and riparian areas inside the 400-meter-wide[a] corridors; habitat, including jurisdictional wetlands outside the corridor that could be disturbed by rail line construction and operations; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flows; migratory ranges of big game animals that could be affected by the presence of a branch rail line
Cultural resources	Lands inside the 400-meter-wide rail corridors
Socioeconomic environments	Clark, Lincoln, Nye and other counties that a potential branch rail line would traverse
Public health and safety	800 meters[b] on each side of the rail line for incident-free transportation, 80-kilometer[c] radius for potential impacts from accident scenarios
Noise and vibration	Inhabited commercial and residential areas where noise and vibration from rail line construction and operations could be a concern
Aesthetics	The landscapes along the potential rail corridors with aesthetic qualities that could be affected by construction and operations
Utilities, energy, and materials	Local, regional, and national supply infrastructure that would be required to support rail line construction and operations
Environmental justice	Locations of minority, low-income, and Native American populations along the rail implementing alternatives; includes the regions of influence for each of the preceding individual subject or impact areas

a. 400 meters = 0.25 mile.
b. 800 meters = 0.5 mile.
c. To convert kilometers to miles, multiply by 0.62137.

3.2.2.1.1 *Land Use and Ownership*

Table 3-36 summarizes the estimated land commitment and current ownership or control of the land in each rail corridor. It addresses both the representative corridor and the range of values applicable to corridor variations. Public lands in and near the corridors are used for a variety of activities including grazing, mining, and recreation. All public land in the Caliente, Carlin, Jean, and Valley Modified Corridors is open to mining and mineral leasing laws and offroad vehicle use, with restrictions in some areas (DIRS 101504-BLM 1979, all; DIRS 101523-BLM 1994, all; DIRS 103080-BLM 1999, all). The rail corridor descriptions, unless otherwise noted, are from DIRS 104993-CRWMS M&O (1999, all), DIRS 101214-CRWMS M&O (1996, all) and DIRS 104560-YMP (1998, all).

Table 3-36. Land ownership for the candidate rail corridors.[a]

Corridor	Totals (km^2)[b,c]	Land in corridor — Ownership or control (percent)[d] BLM	USAF	DOE	Private	Tribal	Other
Representative corridors							
Caliente	205	188 (92)	11 (5)	4.6 (2)	0.9 (<1)	0	0
Carlin	208	179 (86)	11 (5)	4.6 (2)	14 (7)	0	0
Caliente-Chalk Mountain	138	78 (57)	22 (16)	38 (27)	0.8 (<1)	0	0
Jean	72	60 (83)	0	8.5 (12)	3.5 (5)	0	0
Valley Modified	63	34 (53)	7 (11)	21 (32)	0.2 (<1)	0	1.8 (3)
Ranges for corridors with variations (all in km^2)							
Caliente	205 - 221	188 - 216	0 - 11	4.6	0.9 - 2.5	0 - 1.6	0
Carlin	205 - 218	177 - 201	0 - 11	4.6	7.3 - 1.5	0 - 1.6	0
Caliente-Chalk Mountain	138 - 153	77 - 89	22	32 - 38	0.8 - 1.1	0	0
Jean	72 - 82	60 - 69	0	8.5	0.1 - 3.5	0	0
Valley Modified	63 - 65	30 - 37	3.6 - 7.5	21	0 - 0.2	0	1.7 - 4.1

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert square kilometers (km^2) to acres, multiply by 247.1.
c. Totals might differ from sums due to rounding.
d. Bureau of Land Management (BLM) property is public land administered by the Bureau; U.S. Air Force property is the Nellis Air Force Range; DOE property is the Nevada Test Site; tribal land is the Timbisha Shoshone Trust Lands; and the Other designation is the Desert National Wildlife Range managed by the Fish and Wildlife Service.

Caliente. Most of the lands associated with the Caliente Corridor (92 percent) are public lands managed by the Ely, Battle Mountain, and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (DIRS 101523-BLM 1994, all), the *Department of the Interior Final Environmental Impact Statement, Proposed Domestic Livestock Grazing Management Program for the Caliente Area* (DIRS 101504-BLM 1979, all), the *Final Legislative Environmental Impact Statement, Timbisha Homeland* (DIRS 154121-DOI 2000, all) the *Caliente Management Framework Plan Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat* (DIRS 103080-BLM 1999, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

The U.S. Air Force uses about 5 percent of the lands associated with the Caliente Corridor. The corridor crosses the western boundary of the Nellis Air Force Range near Goldfield and again northeast of Scottys Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all).

DOE uses about 2 percent of the lands associated with the Caliente Corridor. The corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all).

Less than 1 percent of the land associated with the Caliente Corridor is private. The corridor crosses private land near Caliente.

The Caliente Corridor (Chapter 2, Figure 2-26) begins in Lincoln County, at an existing section of the Union Pacific Railroad at Eccles, and moves north across mostly Bureau of Land Management lands toward U.S. 93 near Comet Siding, which is south of Panaca. Two alternate sections are being evaluated as the beginning point of this corridor. One is west of a section of the Union Pacific Railroad at Crestline [approximately 3.2 kilometers (2 miles) west of the Dixie National Forest]. From that point it continues west across Bureau of Land Management lands to the point south of Panaca where it joins the main corridor. The other alternate section originates at the Town of Caliente. This section travels north along an existing Union Pacific rail line, running parallel to U.S. 93 to the intersection with the main rail corridor in the same area just south of Panaca. Although the 1990 Bureau of Land Management Master Title Plats indicate that the former Union Pacific right-of-way remains active, the right-of-way ownership for the abandoned rail bed is not clear. Each of these starting sections passes through Meadow Valley Wash. Approximately 3.2 kilometers (2 miles) north of this corridor (just north of Panaca) is the Cathedral Gorge State Park.

The section from Caliente has seen more development and has more inhabitants than the Crestline and the Eccles corridor initiation locations. A utility transmission line extends from Caliente to an area west of Panaca. The Eccles, Caliente, and Crestline Options cross private lands. There are numerous houses, farms, and ranches north of Caliente and extending toward Panaca. Areas of ponded water and streams associated with the Meadow Valley Wash occur through this area along the eastern side of U.S. 93 (which in this area is part of the State Scenic Byway). The Crestline and Caliente Options cross two rights-of-way: one for U.S. 93 and one telephone; the Eccles Option does not cross any rights-of-way. Past the area where the alternate starting sections converge, the corridor passes west on Bureau of Land Management lands near Bennett Springs Road, moves through the Highland Range in the area of Bennett Pass, and continues across Bureau land in the northern section of the North Pahroc Range. Through this section the corridor passes through two pipeline, one telephone, and two road rights-of-way, and east of a wilderness study area. The corridor then moves through Bureau lands west of Nevada State Route 318, along the Lincoln/Nye County line north of the Seaman Range. The corridor passes just north of the Weepah Springs Wilderness Study Area located in the vicinity of Timber Mountain in Lincoln County.

The rail corridor splits in the area of Timber Mountain Pass, with a possible section (the White River Alternate) going north of the Seaman Range into the White River Valley and then passing back to the south and west along and through the Golden Gate Range. The corridor continues on Bureau of Land Management lands in a general southwesterly direction and back into Lincoln County through Garden and Sand Spring Valleys. In Garden Valley, the corridor and the Garden Valley Alternate wind around private land. The corridor crosses one road and one pipeline right-of-way, and five oil or gas leases. The Garden Valley Alternate crosses two road and two pipeline rights-of-way. The corridor continues on Bureau land and passes generally to the southwest into Nye County, to land around the Reveille Range north of the Cedar Pipeline Ranch. It then turns north toward Warm Springs, passing between the Reveille and Kawich Ranges, and passing to the east of the Eden Creek Ranch. As the corridor passes between the southern portion of the Kawich and South Reveille Ranges, it passes just east of the Kawich Wilderness Study Area and encroaches on the South Reveille Wilderness Study Areas. The corridor turns southwest again toward the Nellis Air Force Range, passing the Town of Golden Arrow and the Reeds Ranch, which is just north of the Nellis Range. Also north of the Nellis Range, the Kawich Range contains several ranches and small towns and communities, as well as abandoned and current mining operations.

The Toiyabe National Forest is approximately 6.4 kilometers (4 miles) northwest of the corridor as it passes north of the Kawich Range. Numerous two-track roads surround the Kawich Range providing access to grazing allotments, mining claims, and recreational areas. The corridor then passes along the northern boundary of the Nellis Air Force Range through Ralston Valley. From the merging of the Garden Valley Alternate to the western boundary of the Nellis Range, the corridor crosses or travels along two Bureau of Land Management utility corridors. The corridor also crosses two road, two pipeline, and two powerline rights-of-way. It then turns south along the western boundary of the Nellis Range. Both gravel and two-track roads are present in that area, and throughout the remainder of the corridor, with many entering the Nellis Range.

The corridor splits east of the Town of Goldfield, with the alternate segment going west of Blackcap Mountain, through Bureau of Land Management land and two parcels of private property to the south along the Nye/Esmeralda County line. The corridor traverses a section on the Nellis Air Force Range. The corridor and the alternate segment rejoin in Bureau land along the Nye/Esmeralda County line near the Town of Ralston.

The corridor proceeds south until it splits again around the Town of Scottys Junction in Nye County. One segment, the Bonnie Claire Alternate, passes to the west, crossing U.S. 95 and State Route 267. This western segment passes through 11 square kilometers (2,800 acres) of formerly Bureau of Land Management lands transferred to the Timbisha Shoshone. This parcel of land is being proposed for Tribal economic development (tourism) and Tribal housing (DIRS 154121-DOI 2000, all). In addition to rights-of-way for U.S. 95 and State Route 267, the Bonnie Claire Alternate crosses two powerline and one telephone rights-of-way. It passes through a portion of private land south of U.S. 95. The corridor crosses into the Nellis Air Force Range for a short distance northeast of Scottys Junction before moving back into Bureau of Land Management land. The alternate segment merges with the corridor, which then follows U.S. 95 toward the Town of Beatty, which it passes to the east. A minor segment, the Oasis Alternate, goes slightly farther east of Beatty before merging with the corridor. A little farther to the southeast, the Beatty Wash Alternate then diverges for a short distance until it realigns with the corridor and crosses a Bureau of Land Management utility corridor several times.

Death Valley National Park, west of Beatty at the point closest to the rail corridor, is approximately 11 kilometers (7 miles) to the west. The area surrounding Beatty and extending southeast toward Amargosa Valley has several small towns and numerous current and historic mining operations. There are also campgrounds along U.S. 95. The corridor bypasses most of these areas by moving between Beatty and the Nellis Air Force Range. It continues generally to the south and enters DOE property west of Yucca Mountain and north of the Town of Amargosa Valley.

Carlin. Most of the lands associated with the Carlin Corridor (about 86 percent) are public lands managed by the Battle Mountain and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Draft Shoshone-Eureka Resource Management Plan and Environmental Impact Statement* (DIRS 103077-BLM 1983, all), the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (DIRS 101523-BLM 1994, all), the *Final Legislative Environmental Impact Statement, Timbisha Homeland* (DIRS 154121-DOI 2000, all) and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

The U.S. Air Force uses about 5 percent of the lands associated with the Carlin Corridor. The combined Carlin/Caliente Corridor crosses into the western portion of the Nellis Air Force Range near Goldfield and again northeast of Scottys Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 2 percent of the lands associated with the Carlin Corridor. The combined Carlin/Caliente Corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

About 7 percent of the land associated with the Carlin Corridor is private. The corridor crosses private roads in the northern part of the route, from Beowawe through Crescent Valley.

The Carlin Corridor (Chapter 2, Figure 2-26) begins near the Town of Beowawe in Eureka County, at an existing Union Pacific Railroad line. The corridor moves south along Crescent Valley through a mix of private and Bureau of Land Management lands that extend south of the Town of Crescent Valley, near the Dean Ranch. The corridor crosses numerous gravel and two-track roads, most of which lead to adjoining valleys, ranches, or grazing allotments in Crescent Valley and in the adjacent mountains. The corridor runs east of State Route 306 and continues south toward the Dean Ranch.

Just north of the Dean Ranch and east of State Route 306, the corridor splits. The corridor itself crosses State Route 306 to the west and continues south and west of the Dean Ranch, and the alternate segment travels south and east of the Dean Ranch. The two rejoin south of the ranch on Bureau of Land Management land near the Cortez Airstrip west of the Cortez Gold Mine. An expansion of the Cortez Gold Mine operations, recently approved by the Bureau of Land Management (DIRS 155095-BLM 2000, all), involves the disturbance of an additional 18 square kilometers (4,450 acres) of public lands. This action includes expansion of an existing open pit, extension of process solution pipelines, modifications to the existing road between Gold Acres and the Cortez milling facility, the increase of waste rock and tailings facilities, and a pipeline right-of-way from the mine to the Dean Ranch for supplying water to the ranch. The corridor passes from Eureka County into Lander County near the Dean Ranch. Through Crescent Valley it crosses private lands and two road, one powerline, and two telephone rights-of-way. One of the road rights-of-way runs from the Gold Acres Mine to the Cortez Mine milling facility. The Crescent Valley Alternate crosses private lands, one right-of-way, and another road with no right-of-way listed. Near the Town of Gold Acres, the Gold Acres Mine and its spoils pile are the dominant features in the valley. There are numerous active and abandoned mine sites in the area of the Shoshone Range and the Cortez Mountains. Also in this area are several small towns and numerous ranches in the Crescent Valley and Grass Valley.

The corridor passes east and south of the Cortez Airstrip and through a northern portion of the Toiyabe Range that is not part of the Toiyabe National Forest. In this section of the Toiyabe Range, there is a split in the corridor for engineering design reasons. The corridor passes into Grass Valley west of Hot Springs Point, extending to the south, east of the Cowboy Rest Ranch. It follows the western side of the valley until it splits north of the Grass Valley Ranch. The corridor segment runs west of the Grass Valley Ranch, where it crosses private lands adjacent to Bureau of Land Management lands. Roads connect Grass Valley to the surrounding areas, most of which appear to be two-track roads that extend from main gravel roads in the valley to the mountainous areas on both sides of the valley. Some of these two-track roads might be for recreation, but are probably used to access Bureau grazing or mining allotments in the area. The corridor follows Bureau lands and continues to the south. The alternate segment (the Steiner Creek Alternate) passes to the east of the Grass Valley Ranch, along the western base of the Simpson Park Mountains. The Steiner Creek Alternate passes close to the Simpson Park Wilderness Study Area in Lander County just east of the Grass Valley Ranch. The corridor and alternate segments rejoin near Bates Mountain and continue south through Bureau lands in Rye Patch Canyon, still following the western edge of the Simpson Park Mountains. In this area, the corridor splits again, still on Bureau lands. The corridor and the Rye Patch Alternate diverge to bypass sensitive habitat at Rye Patch Spring. Both cross two road rights-of-way. At this point, the corridor splits into two major variations, the Big Smoky Valley Option and the Monitor Valley Option, both of which run mostly through Bureau lands. Soon after this split, both cross the Nye/Lander County line.

The Big Smoky Valley portion of the corridor begins just south of the Givens Ranch in Rye Patch Canyon and continues south along the eastern side of the valley. U.S. 50, a State Scenic Byway, crosses the Valley from east to west, just to the south of the Givens Ranch. The Lander/Nye County line is approximately 26 kilometers (16 miles) south of U.S. 50. South of the county line, the Big Smoky Valley Alternate crosses three road, one flume, four powerline, and two pipeline rights-of-way, and a Desert Land Entry withdrawal parcel west of the Town of Hadley. It also passes through a Bureau of Land Management utility corridor. The Big Smoky Valley is comprised of Bureau lands and private property. The Bureau lands consist primarily of grazing allotments. The main road, State Route 376, runs along the western side of the valley. Other roads cross the valley, generally running east-west, leading to the National Forest on both sides of the valley and to small communities and public recreation areas. Some of these are Forest Service roads that cross the National Forest and connect with State or other Forest Service roads in adjacent valleys. One of the most frequently used public recreation areas is Peavine Public Campgrounds in the southern part of the Toiyabe National Forest in the Toiyabe Range. There are numerous ranches, most along the western edge of the valley. Small roads (two-tracks) run along the valley floor, generally through grazing allotments. A power line runs along the route, just west of the Town of Millers, and continues north up the valley near Manhattan. In this area, the valley is flanked by the Toquima and Toiyabe Ranges, both of which are part of the Toiyabe National Forest. The southern portion of Big Smoky Valley narrows, and there are many small towns in this portion of the valley, limiting the opportunity to avoid private land.

The corridor passes west of State Route 376 and proceeds to the west of the Round Mountain Golf Course near the Town of Hadley and its airport. The route follows the western edge of the valley and continues to the south near the San Antonio Ranch, running between the Town of Midway Station and the San Antonio Mountains, where there is a large section of private land, most of which probably is associated with mining. The route crosses Secondary State Route 89 and, after crossing into Esmeralda County, continues south across U.S. 95/6 west of Tonopah. It then turns to the southeast toward Nellis Air Force Range, crossing U.S. 95 again and moving south and east of the Town of Klondike, where it joins with the Monitor Valley Alternate.

The Monitor Valley Option runs east from the Rye Patch Canyon area along the Simpson Park Mountains, near the Hicks Summit Petroglyph Recreation Area. It crosses U.S. 50 and extends south into Monitor Valley, generally following Stoneberger Creek and adjacent to a two-track road along the western side of the valley. It then continues through the valley east of Secondary State Route 82 and moves into Nye County, passing east of the Monitor Ranch between Potts and the Toquima Range to the west. Monitor Valley is bounded on both east and west by the Toiyabe National Forest, which includes several wildlife areas, recreation areas, ranches, and small communities. Numerous roads cross the valley, leading through the adjacent mountain ranges or to isolated ranches and grazing allotments. The option remains to the east of Secondary State Route 82, continuing south to the community of Belmont, where the valley narrows, and follows along or just west of Secondary State Route 82. Past Belmont, the option follows Secondary State Route 82 to its intersection with State Route 376 and then continues south through Ralston Valley, crossing U.S. 6 west of the Tonopah Municipal Airport. There is a state prison on the western side of State Route 376, approximately 13 kilometers (8 miles) north of U.S. 6. The option continues south until it rejoins the corridor near the Nye/Esmeralda County line. In Monitor Valley, the option crosses one telephone, two road, and one pipeline rights-of-way. There are two Desert Land Entry parcels between the Town of Hadley and the Nye/Esmeralda County line.

The rejoined corridor and option intersect the Caliente Corridor (as described above) near Mud Lake in the northwest corner of the Nellis Air Force Range before continuing to Yucca Mountain. As with the Caliente Corridor, the Carlin Corridor's Bonnie Claire Alternate passes through an area recently designated for the creation of a section of the Timbisha Shoshone Reservation on lands transferred from the Bureau of Land Management (DIRS 154121-DOI 2000, all).

Caliente-Chalk Mountain. Most of the lands associated with the Caliente-Chalk Mountain Corridor (about 57 percent) are public lands managed by the Ely Office of the Bureau of Land Management. Detailed information on land use is available in DIRS 101504-BLM (1979, all) and DIRS 103080-BLM (1999, all).

The U.S. Air Force uses about 16 percent of the lands associated with the Caliente-Chalk Mountain Corridor. The corridor enters the Nellis Air Force Range west of Rachel, Nevada, and travels south through the range. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 27 percent of the lands associated with the Caliente-Chalk Mountain Corridor. The corridor crosses the northern border of the Nevada Test Site and travels to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

Less than 1 percent of the lands associated with the Caliente-Chalk Mountain Corridor is private. The combined Caliente and Caliente-Chalk Mountain Corridor crosses private lands near Caliente.

The beginning portion of the Caliente-Chalk Mountain Corridor (Chapter 2, Figure 2-26) is the same as the beginning portion of the Caliente Corridor described above. The two corridors and their variations are identical until they reach the area of Sand Spring Valley.

At Sand Spring Valley, the Caliente-Chalk Mountain Corridor splits from the Caliente Corridor and continues on Bureau of Land Management land to pass generally south along the Lincoln/Nye County line. The corridor crosses State Route 375 and enters the Nellis Air Force Range east of Queen City Summit.

The Caliente-Chalk Mountain Corridor continues south just west of Chalk Mountain and into the northern portion of Emigrant Valley. It passes numerous paved and two-track roads through this area. The corridor passes almost due south into the Nevada Test Site. Once inside the Test Site the corridor divides just north of the main infrastructure area. The Orange Blossom Road Option continues generally to the south just east of the infrastructure area in the eastern portion of the Test Site. This option continues southeast of French Peak and then passes generally to the west around infrastructure and just north of Skull Mountain. It continues generally westward, passing infrastructure south of the Calico Hills, crossing Fortymile Wash, and into the proposed repository area. It crosses a power right-of-way twice and a waterline right-of-way. It also crosses Nevada Test Site roads.

The Mercury Highway Option splits from the corridor just north of the large Nevada Test Site infrastructure area. This option turns generally south along the east of the Elena Range through Yucca Flat and the center of the Test Site, crossing roads and bypassing existing infrastructure until it joins with the Orange Blossom Road Option just north of Skull Mountain and continues to the proposed repository site.

The Area 4 Alternate splits from the Mercury Highway Option along the western edge of the Nevada Test Site infrastructure area in the vicinity of Syncline Ridge where it joins with the Tonopah Option. This option crosses the Mercury Highway.

The Mine Mountain Alternate splits from the Area 4 Alternate in the vicinity of Mine Mountain Junction to minimize impacts to cultural sites in the area. It splits for only a short distance and then rejoins the Area 4 Alternate.

The Tonopah Option travels just inside the northern Nevada Test Site boundary westward until it begins to turn to the south along the eastern edge of the Elena Range bypassing Test Site infrastructure areas. The route passes along the western edge of Barren Wash until it strikes westward south of the Calico Hills and continues across Fortymile Wash.

The Caliente-Chalk Mountain Corridor crosses lands in which paved, gravel, and two-track roads are abundant. These roads provide access to grazing and mining allotments and recreational areas on Bureau of Land Management lands. Some roads provide access to recreational areas on State and Federal lands (Humboldt National Forest).

Jean. Most of the lands associated with the Jean Corridor (about 83 percent) are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in DIRS 103079-BLM (1998, all).

DOE uses about 12 percent of the lands associated with the Jean Corridor. The corridor enters the Nevada Test Site near Amargosa Valley traveling north to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

About 5 percent of the land associated with the Jean Corridor is private. The corridor crosses private lands in the Pahrump Valley.

The Jean Corridor consists of the Wilson Pass Option (the corridor) and the Stateline Pass Option starting sections (Chapter 2, Figure 2-26). The Wilson Pass Option begins along the Union Pacific rail line just north of Jean. The corridor extends northwest and runs north of State Route 161, along Bureau of Land Management lands toward Goodsprings, and along the southern edge of the Bird Spring Range. It crosses two pipeline, three road, and two powerline rights-of-way.

The corridor passes through the Bureau of Land Management mining area containing the Bluejay, Snowstorm, and Pilgrim Mines, and runs within about 2 kilometers (1.2 miles) south of the Toiyabe National Forest in the Spring Mountains. The area contains a number of access roads to the mine sights. Several State and access roads associated with the National Forest cross the corridor. The corridor passes just to the south of the National Forest and traverses Wilson Pass along Bureau lands, continuing to the northwest until its intersection with State Route 160. It then continues across a Bureau utility corridor and continues on Bureau lands north of State Route 160 until it intersects the Stateline Pass Option.

The Stateline Pass Option begins in Ivanpah Valley along the Union Pacific rail line south of Jean and just north of Roach Lake, in an area that Clark County is proposing as the location for a cargo airport and other purposes. This option passes through Bureau of Land Management lands, going south through mining areas along the California/Nevada state line and then turns northwest, skirting private land around the Sandy Valley community. It crosses two pipeline, two road/highway, and one powerline and telephone rights-of-way. It also passes near the Stateline Wilderness Area.

Continuing along Bureau of Land Management lands just north of Secondary State Route 16, the Stateline Pass Option crosses State Route 160 to intersect the Jean Corridor east of Pahrump. In the Pahrump vicinity, State roads access the national forests to the north, and there are several tracks and trails in the area.

The corridor then crosses from Clark County into Nye County before splitting, with the corridor passing close to the Town of Pahrump and the Pahrump Valley Alternate passing closer to the Spring Mountains east of Pahrump. The corridor segment crosses several parcels of private property. The alternate segment abuts the Toiyabe National Forest and a Bureau of Land Management utility corridor and then enters the utility corridor. The corridor and alternate segments rejoin near the community of Johnnie, just east of State Route 160. There are several tracks and trails in this area. The corridor continues to the north until it passes just south of U.S. 95, where it turns northwest through Bureau of Land Management land north of the Ash Meadows National Wildlife Refuge [approximately 14 kilometers (9 miles) west of Johnnie].

Continuing to the north across the Amargosa Desert, the corridor crosses State Route 160, several gravel roads, and a number of two-track roads on Bureau of Land Management land. The corridor crosses a Bureau utility corridor, two telephone, and two powerline rights-of-way. It then crosses U.S. 95 and enters Nevada Test Site property northeast of the Town of Amargosa Valley and continues to the proposed repository site at Yucca Mountain.

Valley Modified. About 53 percent of the lands associated with the Valley Modified Corridor are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in DIRS 103079-BLM (1998, all).

The U.S. Air Force uses about 11 percent of the lands associated with the Valley Modified Corridor. The corridor crosses Nellis Air Force Base northeast of Las Vegas and the Nellis Air Force Range near Indian Springs. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 32 percent of the lands associated with the Valley Modified Corridor. The corridor enters the Nevada Test Site near Mercury, traveling northwest to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

The Fish and Wildlife Service manages about 3 percent of the lands associated with the Valley Modified Corridor as part of the Desert National Wildlife Refuge, which was established in 1936 for the protection and preservation of desert bighorn sheep. Portions of this refuge overlap the Nellis Air Force Range and are controlled jointly by the Air Force and the Fish and Wildlife Service. Use and public access to the joint-use area of the Desert National Wildlife Range and Nellis Air Force Range are restricted by a memorandum of understanding (DIRS 103472-USAF 1999, Appendix C). The Valley Modified corridor passes potential Wilderness Study Areas under consideration by Congress. The Quail Springs Wilderness Study Area, and the Nellis Air Force Range A, B, and C Wilderness Study Areas, located on Bureau of Land Management lands, were inventoried under the 1976 Federal Land Policy and Management Act in support of the 1964 Wilderness Act. Wilderness Study Areas cannot be altered unless they have been released from the program. At this time, there has been no action to release these areas.

The Valley Modified Corridor begins along the Union Pacific rail line in the Apex/Las Vegas area of Clark County, Nevada (Chapter 2, Figure 2-26). The corridor has two possible starting locations and two possible variations, until they merge north of the City of Las Vegas in the Apex area. Clark County is proposing an industrial park on lands transferred from the Bureau of Land Management that would encompass the primary corridor origination location. The Valley Connection starting segment begins in a Bureau corridor near private property in the vicinity of the City of North Las Vegas and travels along the Union Pacific rail line toward Apex until it turns west. The alternate segment crosses three powerline rights-of-way before turning to the west.

After the corridor turns west from either starting location, there are again two options--the corridor itself and the Sheep Mountain Option slightly north of the corridor. Both the corridor and the alternate cross Bureau of Land Management lands and then enter the Nellis Small Arms Range. After leaving the Small Arms Range, they cross the Nellis Air Force Range Wilderness Study Areas A, B, and C and then pass through the Desert National Wildlife Range and the Quail Springs Wilderness Study Area. Both cross several gravel and two-track roads, some of which enter the Desert National Wildlife Range to the north. The corridor and alternate merge before the corridor crosses the Wildlife Range and the Quail Springs Wilderness Study Area a second time. A powerline follows U.S. 95 from its intersection with State Route 157 to Mercury, where it enters the Nevada Test Site.

After the corridor and alternate join, the corridor continues to the northwest through the Las Vegas Valley, passing northeast of U.S. 95 and just to the north of Floyd Lamb State Park and the Las Vegas Paiute Reservation. It crosses several roads and two-track roads that lead into the Desert National Wildlife Range. Continuing to the northwest and running just north of U.S. 95, the corridor crosses an area close to the Desert National Wildlife Range, Desert View Natural Environmental Area, and Nellis Air Force Range.

The corridor then splits east of Indian Springs, with both segments continuing west and crossing from Clark County into Nye County east of Mercury. The northern segment (the corridor) bypasses Indian Springs and Cactus Springs, running to the north across the Desert National Wildlife Range and Bureau of Land Management lands until it merges with the southern segment just south of Mercury. The corridor crosses existing roads and tracks in the area south of Mercury, in the vicinity of Desert Rock.

The Indian Hills Alternate passes south of U.S. 95 across Bureau of Land Management lands until it crosses back to the north of U.S. 95 and joins the corridor south of Mercury. After the routes join, the corridor enters DOE property just southwest of Mercury and continues south of Skull Mountain to Yucca Mountain.

3.2.2.1.2 *Air Quality and Climate*

This section contains information on the existing air quality in areas through which the candidate rail corridors pass. It also provides background on the general climate in those areas.

Air Quality. The Caliente, Carlin, Caliente-Chalk Mountain, and Jean Corridors pass through rural parts of Nevada that are either unclassifiable or in attainment for criteria pollutants (DIRS 148123-EPA 1999, all; DIRS 149905-EPA 1999, all; DIRS 149906-EPA 1999, all; DIRS 149907-EPA 1999, all). There are no State air-quality monitoring stations in these corridors (DIRS 103404-Bureau of Air Quality 1999, pp. A1-1 through A1-9).

The Valley Modified Corridor crosses central Clark County at the north end of the Las Vegas Valley and continues in a northwest direction toward the Nevada Test Site. The air quality in the part of the corridor that passes through the Las Vegas Valley and extends part of the way to Indian Springs is in nonattainment for particulate matter with a diameter of less than 10 micrometers (PM_{10}). Clark County adopted a revised implementation plan in 2001 for demonstrating PM_{10} attainment (DIRS 155557-Clark County 2001, Executive Summary) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration of the 24-hour standard from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. A decision has not been made on the county's request for an extension to the attainment period. The Environmental Protection Agency has acknowledged the request, but has not yet completed its formal review of the revised implementation plan (DIRS 156896-Davis 2001, all).

In addition, the Las Vegas Valley air basin is in nonattainment for the 3-hour carbon monoxide standard, largely the result of vehicular emissions. Clark County adopted a State Implementation Plan for carbon monoxide to achieve the attainment criteria by December 2000 (DIRS 156706-Clark County 2000, all). The Plan outlines a methodology to maintain acceptable carbon monoxide concentrations through transportation planning and control measures. The Environmental Protection Agency has deemed the motor vehicle carbon monoxide estimates indicated in the Plan *adequate* (65 *FR* 71313; November 30, 2000). In 2000, monitoring results indicated that the Plan criteria has been met (DIRS 157158-EPA 2000, all); however, the area is still officially classified as in nonattainment.

Climate. There are two general climate descriptions for the five rail corridors: one for the three corridors that approach the Yucca Mountain site from the north and one for the two corridors that approach the site from the south or southeast. The Caliente, Carlin, and Caliente-Chalk Mountain Corridors approach from the north and cross a number of mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nye County the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches); annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters

(2 inches) an hour can occur in the summer. Each of the three corridors approaching Yucca Mountain from the north pass through central Nye County, and DOE believes that the climate described is a reasonable average for conditions along these corridors.

The Jean and Valley Modified Corridors approach the Yucca Mountain site from the south where precipitation is generally between 10 and 20 centimeters (4 and 8 inches) per year and snowfall is rare. Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52).

3.2.2.1.3 *Hydrology*

This EIS discusses hydrologic conditions in terms of surface water and groundwater.

3.2.2.1.3.1 Surface Water. Researchers studied the alternative rail corridors for their proximity to sensitive environmental resources, including surface waters and riparian lands (DIRS 104593-CRWMS M&O 1999, Appendixes E, F, G, H, and I). The goal in planning the corridors was to avoid springs and riparian lands by 400 meters (1,300 feet) if possible. Table 3-37 summarizes potential surface-water-related resources along the candidate corridors. It lists resources within the 400-meter corridor or within a 1-kilometer (0.6-mile) region of influence along the corridor. Table 3-38 presents similar information for the variation segments. The last column of Table 3-37 identifies water resources that DOE would avoid by using a specified variation rather than the corresponding segment along the rail corridor. Water resources along the variation segment that would be "substituted" can be linked from Table 3-38. If the same water resource would be in proximity to both the corridor and variation segment, it is marked as "Avoided" in Table 3-37, but appears again in Table 3-38 for the variation.

Potential hydrologic hazards along the rail corridors include flash floods and debris flow. All corridors have potential flash flooding concerns. DOE would design and build a rail line that would be able to withstand a 100-year flood event safely.

Appendix L of this environmental impact statement is a floodplain/wetland assessment for the proposed repository action, including the Nevada transportation routes. This appendix includes the results of efforts to identify flood zones along the potential rail corridors and their associated alternate segments through the use of Flood Insurance Rate Maps published by the Federal Emergency Management Agency. The flood zone maps do not provide complete coverage for any of the rail corridors primarily because there are none for the large areas of the Nevada Test Site and the Nellis Air Force Range. In some areas the maps do, however, provide a good indication of 100-year flood zones that might exist in the rail corridors. Consistent with the distribution of surface-water resources listed in Table 3-37, the floodplain information in Appendix L (see Table L-4) indicates the greatest number of different flood zones would occur along the Caliente and Carlin Corridors.

3.2.2.1.3.2 Groundwater. Groundwater basins that the candidate rail corridors cross represent part of the potentially affected environment. As described for groundwater in the immediate region of Yucca Mountain (Section 3.1.4.2.1), the State of Nevada has been divided into groundwater basins and sub-basins. The sub-basins are called hydrographic areas. A map of these areas (DIRS 101486-Bauer et al. 1996, p. 543) was overlain with a drawing of the proposed rail corridors to produce a reasonable approximation of the areas that would be crossed by each corridor. Table 3-39 lists results of this effort for the rail corridors. Table 3-40 presents similar information for the different segments associated with the corridor variations. The tables also list estimates of the perennial yield for each hydrographic area crossed and if the area is a State Designated Groundwater Basin [a hydrographic area in which the permitted water rights approach or exceed the estimated perennial yield and the water resources are depleted or require additional administration, including a State declaration of preferred uses (municipal

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Table 3-37. Surface-water-related resources along candidate rail corridors[a] (page 1 of 2).

Rail corridor	Distance from corridor (kilometers)[b]	Feature	Avoided by variation (Yes or No)[c]
Caliente			
Eccles Siding to Meadow Valley Wash	Within	Riparian area/stream – corridor crosses and is adjacent to stream and riparian area in Meadow Valley Wash	Y-1, 2
Meadow Valley to Sand Spring Valley	1.0	Spring – Bennett Spring, 3.2 kilometers southeast of Bennett Pass	N
	0.05 - 2.6	Springs – group of five springs (Deadman, Coal, Black Rock, Hamilton, and one unnamed) east of White River	N
	Within	Riparian/river – corridor parallels (and crosses) the White River for about 10 kilometers. August 1997 survey found river to be mostly underground with ephemeral washes above ground.	N
	0.8	Spring – McCutchen Spring, north of Worthington Mountains	N
Sand Spring Valley to Mud Lake	0.02	Spring – Black Spring, south of Warm Springs	N
Mud Lake to Yucca Mountain	Within - 2.5	Springs – numerous springs and seeps along Amargosa River in Oasis Valley	Y-8
	Within - 0.3	Riparian area/stream – designated area east of Oasis Valley, flowing into Amargosa River, also riparian area, with persistent water and extensive wet meadows near springs and seeps	Y-8
	0.3 - 1.3	Springs – group of 13 unnamed springs in Oasis Valley north of Beatty	Y-8
Carlin			
Beowawe to Austin	0.5	Spring – Tub Spring, northeast of Red Mountain	Y-11
	0.8	Spring – Red Mountain Spring, east of Red Mountain	Y-11
	0.9	Spring – Summit Spring, west of corridor and south of Red Mountain	N
	0.4	Spring – Dry Canyon Spring, west of Hot Springs Point	N
	0.8	Spring – unnamed spring on eastern slope of Toiyabe Range, southwest of Hot Springs Point	N
	1.0	Riparian area – intermittent riparian area associated with Rosebush Creek, in western Grass Valley, north of Mount Callaghan	Y-12
	Within	Riparian/creek – corridor crosses Skull Creek, portions of which have been designated riparian areas	Y-12
	Within	Riparian/creek – corridor crosses intermittent Ox Corral Creek; portions designated as riparian habitat. An August 1997 survey found creek dry with no riparian vegetation present	Y-12
	0.1	Spring – Rye Patch Spring, at north entrance of Rye Patch Canyon, west of Bates Mountain	N
	Within	Riparian area – corridor crosses and parallels riparian area in Rye Patch Canyon	Y-13
	0.7	Spring – Bullrush Spring, east of Rye Patch Canyon	N
Austin to Mud Lake	0.8	Springs – group of 35 unnamed springs, about 25 kilometers north of Round Mountain on east side of Big Smoky Valley	Y-14
	0.6	Riparian area – marsh area formed from group of 35 springs	Y-14
	0.6	Spring – Mustang Spring, south of Seyler Reservoir	Y-14
	0.3	Riparian/reservoir – Seyler Reservoir (seasonal), west of Manhattan	Y-14

Table 3-37. Surface-water-related resources along candidate rail corridors[a] (page 2 of 2).

Rail corridor	Distance from corridor (kilometers)[b]	Feature	Avoided by variation (Yes or No)[c]
Carlin (continued)			
Mud Lake to Yucca Mountain		See Caliente corridor	
Caliente-Chalk Mountain			
Eccles Siding to Meadow Valley		See Caliente corridor	
Meadow Valley to Sand Spring Valley		See Caliente corridor	
Sand Spring Valley to Yucca Mountain	1.0	Spring – Reitman's Seep, in eastern Yucca Flat, east of BJ Wye	Y-15, 16
	0.8	Spring – Can Spring, on north side of Skull Mountain on Nevada Test Site	Y-15
Jean		None identified	
Valley Modified		None identified	

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).
b. To convert kilometers to miles, multiply by 0.62137.
c. Some water resources would be avoided by corridor variations. These are identified with a "Y" (yes) and a number representing the specific variation from Table 3-38 that avoids the specific resource. Table 3-38 identifies the variation by number and shows the water resources associated with the corridor segment unique to that variation. The same water resource might be in proximity to both the rail corridor and variation segment. In such cases, the resource is marked "Avoided" for the rail corridor here, but appears on Table 3-38 for the variation.

and industrial, domestic supply, agriculture, etc.)] (DIRS 103406-NDWP 1992, p. 18). These are the areas where additional water demand would be most likely to produce an adverse effect on local groundwater resources. Table 3-39 indicates that none of the corridors would completely avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain Corridor would cross only two Designated Basins, one at Panaca Valley near the start of the corridor and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain Corridors split.

The last column of Table 3-39 identifies hydrographic areas that DOE would avoid or cross differently if a corridor variation (also identified in the table) were to be used. In most cases, the variation listed in Table 3-40 would have little or no effect on the hydrographic areas crossed. The Crestline Option, Caliente Option, White River Alternate, Goldfield Alternate, and Stateline Pass Option would involve changing, dropping, or adding a single hydrographic area to those that the rail corridor would cross. The Monitor Valley Option is the only other variation that would make a difference and would result in changing two and adding one to the list of hydrographic areas that the Carlin Corridor would cross.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-11 for the hydrographic areas in the Yucca Mountain region. For simplicity, the perennial yield values listed in Table 3-39 generally come from a single source (DIRS 103406-NDWP 1992, Regions 4, 10, 13, and 14) and, therefore, do not show a range of values for each area. The hydrographic areas in the Yucca Mountain region (that is, areas 225 through 230) are the exception to perennial yield values from the single source. The perennial yield values for these areas are from DIRS 147766-Thiel (1999, pp. 6 to 12), which compiles estimates from several sources. The table lists the lowest values in that document.

The perennial yield value shown for Area 227A is the lowest estimated value presented in DIRS 147766-Thiel (1999, p. 8) and is further divided into 300 acre-feet (370,000 cubic meters) for the eastern third of the area and 580 acre-feet (720,000 cubic meters) for the western two-thirds.

Table 3-38. Surface-water-related resources along unique segments of corridor variations.[a,b]

Variation	Applicable corridor(s)[c]	Water resource features: Distance from corridor (kilometers)[d]	Water resource features: Feature
1. Crestline Option	CL/CM	0.3	Spring - Miller Spring south of SR[e] 319 and southeast of Panaca; important water source for game
		1.0	Spring - Miser Spring south of SR 319 and southeast of Panaca
		Within	Riparian area/stream - variation crosses Meadow Valley Wash stream and riparian area south of Panaca
2. Caliente Option	CL/CM	Within	Riparian area/stream - variation crosses Meadow Valley Wash stream and riparian area south of Caliente
		0.6	Spring - unnamed spring in Caliente
		Within	Spring - unnamed spring in Meadow Valley north of Caliente
		0.5	Springs - two unnamed springs in Meadow Valley north of Caliente
3. White River Alternate	CL/CM		None identified - parallels White River further than rail corridor, but not within 1 kilometer
4. Garden Valley Alternate	CL/CM		None identified
5. Mud Lake Alternate	CL/CR		None identified
6. Goldfield Alternate	CL/CR	0.6	Spring - Tognoni Springs northeast of Goldfield
		0.4	Spring - unnamed spring south of Mud Lake and east of U.S. 95
7. Bonnie Claire Alternate	CL/CR		None identified
8. Oasis Valley Alternate	CL/CR	0.5 - 3.0	Springs - numerous springs and seeps along Amargosa River in Oasis Valley
		Within - 0.3	Riparian area/stream - designated area east of Oasis Valley, flowing into Amargosa River, also a riparian area, with persistent water and extensive wet meadows near springs and seeps
		0.8 - 1.8	Springs - group of 13 unnamed springs in Oasis Valley north of Beatty
9. Beatty Wash Alternate	CL/CR		None identified
10. Crescent Valley Alternate	CR		None identified
11. Wood Spring Canyon Alternate	CR		None identified
12. Steiner Creek Alternate	CR	Within	Riparian area - variation crosses designated riparian area in Water Canyon northeast of Bates Mountain
		Within	Riparian/creek - variation crosses Steiner Creek, a designated riparian area. An August 1997 survey found creek dry and lacking riparian vegetation
13. Rye Patch Alternate	CR	0.1	Riparian area - variation parallels riparian area in Rye Patch Canyon
14. Monitor Valley Option	CR	0.7	Spring - unnamed spring east of variation and east of Toquima Range
		0.2	Riparian area - designated riparian area west of variation, northwest of Belmont. An August 1997 survey found area dry and lacking riparian vegetation.
15. Topopah Option	CM	0.6	Spring - Whiterock Spring north of variation, south of Burnt Mountain
15a. Area 4 Alternate	CM		None identified - avoids Whiterock Spring of the Tonopah Option
15b. Mine Mountain Alternate	CM		None identified - main portion of option still passes Whiterock Spring
16. Mercury Highway Option	CM		None identified
17. Pahrump Valley Alternate	J		None identified
18. Stateline Pass Option	J		None identified
19. Valley Connector	VM		None identified
20. Sheep Mountain Alternate	VM		None identified
21. Indian Hills Alternate	VM		None identified

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).
b. Rail corridors are listed in Table 3-37. Water resources identified in that table that can be avoided by a variation are identified with a number designation that is consistent with the numbering in this table.
c. Rail corridor abbreviations used in the table are defined as follows: CL = Caliente; CM = Caliente-Chalk Mountain; CR = Carlin; J = Jean; VM = Valley Modified.
d. To convert kilometers to miles, multiply by 0.62137.
e. SR = State Route.

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Table 3-39. Hydrographic areas (groundwater basins) crossed by candidate rail corridors.

Rail corridor	Hydrographic area[a] No.	Hydrographic area[a] Name	Perennial yield (acre-feet)[b,c,d]	Designated Groundwater Basin[e,f]	Avoided by variation (Yes or No)[g]
Caliente					
Eccles Siding to Sand Spring Valley	204	Clover Valley	1,000	No	Y-1, 2
	203	Panaca Valley	9,000	Yes	Y-1, 2
	181	Dry Lake Valley	2,500	No	N
	208	Pahroc Valley	21,000	No	Y-3
	171	Coal Valley	6,000	No	Y-3
	172	Garden Valley	6,000	No	N
Sand Spring Valley to Mud Lake	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes	N
	173A	Railroad Valley, southern part	2,800	No	N
	156	Hot Creek	5,500	No	N
	149	Stone Cabin Valley	2,000	Yes	N
	141	Ralston Valley	6,000	Yes	Y-6
Mud Lake to Yucca Mountain	145	Stonewall Flat	100	No	Y-6
	144	Lida Valley	350	No	N
	146	Sarcobatus Flat	3,000	Yes	N
	228	Oasis Valley	1,000	Yes	N
	229	Crater Flat	220	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Carlin	54	Crescent Valley	16,000	Yes	N
Beowawe to Austin	138	Grass Valley	13,000	No	N
	137B	Big Smoky Valley, northern part	65,000	Yes	Y-14
Austin to Mud Lake – Via Big Valley	137A	Big Smoky Valley and Tonopah Flat	6,000	Yes	Y-14
	142	Alkali Spring Valley	3,000	No	Y-14
	145 to 227A	See Caliente Corridor			
Mud Lake to Yucca Mountain					
Caliente-Chalk Mountain	204 to 170	See Caliente Corridor			
Eccles Siding to Sand Spring Valley	158A	Emigrant Valley and Groom Lake Valley	2,800	No	N
Sand Spring Valley to Yucca Mountain	159	Yucca Flat	350	No	N
	160	Frenchman Flat	16,000	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Jean	165	Jean Lake Valley	50	Yes	Y-18
Jean to Yucca Mountain	164A	Ivanpah Valley, northern part	700	Yes	Y-18
	163	Mesquite Valley (Sandy Valley)	2,200	Yes	Y-18
	162	Pahrump Valley	12,000	Yes	N
	230	Amargosa Desert	24,000	Yes	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Valley Modified	212	Las Vegas Valley	25,000	Yes	N
Dike Siding (north of Las Vegas) to Yucca Mountain	211	Three Lakes Valley, southern part	5,000	Yes	N
	161	Indian Springs Valley	500	Yes	N
	225	Mercury Valley	250	No	N
	226	Rock Valley	30	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N

a. Source: DIRS 101486-Bauer et al. (1996, pp. 542 and 543 with corridor map overlay).
b. Source: DIRS 103406-NDWP (1992, Regions 4, 10, 13, and 14), except hydrographic areas 225 through 230 for which the source is DIRS 147766-Thiel (1999, pp. 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet (30 million cubic meters) for the combined area of hydrographic areas 225 through 230.
c. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
d. To convert acre-feet to cubic meters, multiply by 1,233.49.
e. Source: DIRS 148165-NDWP (1999, Regions 4, 10, 13, and 14).
f. "Yes" indicates the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.
g. Some variations would involve crossing different hydrographic areas than those listed here for the rail corridor. In such cases, the portion of the rail corridor that corresponds to the unique variation segment is identified with a "Y" (yes) and a number representing the variation(s) from Table 3-40. Hydrographic areas in which the unique variation segment begins or ends appear both here, with a "Y," and in Table 3-40 with the applicable variation.
h. The perennial yield value shown for Area 227A is the lowest estimated value presented in DIRS 147766-Thiel (1999, p. 8) and is further broken down into 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 720,000 cubic meters (580 acre-feet) for the western two-thirds.

Table 3-40. Hydrographic areas crossed by unique segments of corridor variations.

	Variation	Applicable corridor(s)[a]	Note[b]	Hydrographic area crossed[c] No.	Name	Perennial yield (acre-feet)[d,e]	Designated Groundwater Basin[d]
1.	Crestline Option	CL/CM		197	Escalante Desert	1,000	No
				203	Panaca Valley	9,000	Yes
2.	Caliente Option	CL/CM		203	Panaca Valley	9,000	Yes
3.	White River Alternate	CL/CM		208	Pahroc Valley	21,000	No
				207	White River Valley	37,000	No
				171	Coal Valley	6,000	No
4.	Garden Valley Alternate	CL/CM	(1)	171	Coal Valley	6,000	No
				172	Garden Valley	6,000	No
5.	Mud Lake Alternate	CL/CR	(1)	141	Ralston Valley	6,000	Yes
6.	Goldfield Alternate	CL/CR		141	Ralston Valley	6,000	Yes
				142	Alkali Spring Valley	3,000	No
				145	Stonewall Flat	100	No
7.	Bonnie Claire Alternate	CL/CR	(1)	144	Lida Valley	350	No
				146	Sarcobatus Flat	3,000	Yes
8.	Oasis Valley Alternate	CL/CR	(1)	228	Oasis Valley	1,000	Yes
9.	Beatty Wash Alternate	CL/CR	(2)	228	Oasis Valley	1,000	Yes
				229	Crater Flat	220	No
10.	Crescent Valley Alternate	CR	(1)	54	Crescent Valley	16,000	Yes
11.	Wood Spring Canyon Alternate	CR	(1)	54	Crescent Valley	16,000	Yes
12.	Steiner Creek Alternate	CR	(1)	138	Grass Valley	13,000	No
13.	Rye Patch Alternate	CR	(1)	137B	Big Smoky Valley, north	65,000	Yes
14.	Monitor Valley Option	CR		137B	Big Smoky Valley, north	65,000	Yes
				140A	Monitor Valley, north	8,000	No
				140B	Monitor Valley, south	10,000	No
				141	Ralston Valley	6,000	Yes
15.	Topopah Option	CM	(2)	159	Yucca Flat	350	No
				160	Frenchman Flat	16,000	No
				227A	Fortymile Canyon, Jackass Flats	880	No
16.	Mercury Highway Option	CM	(2)	159	Yucca Flat	350	No
				160	Frenchman Flat	16,000	No
17.	Pahrump Valley Alternate	J	(1)	162	Pahrump Valley	12,000	Yes
18.	Stateline Pass Option	J		164A	Ivanpah Valley, north	700	Yes
				163	Mesquite Valley (Sandy Valley)	2,200	Yes
19.	Valley Connector	VM	(2)	212	Las Vegas Valley	25,000	Yes
20.	Sheep Mountain Alternate	VM	(1)	212	Las Vegas Valley	25,000	Yes
21.	Indian Hills Alternate	VM	(2)	211	Three Lakes Valley, south	5,000	Yes
				161	Indian Springs Valley	500	Yes

a. Rail corridor abbreviations used in the table are defined as follows: CL = Caliente; CM = Caliente-Chalk Mountain; CR = Carlin; J = Jean; VM = Valley Modified.

b. Notes:
   1. The corresponding portion of the rail corridor passes over the same hydrographic area(s) for approximately the same distance(s).
   2. The corresponding portion of the rail corridor passes over the same hydrographic area(s), but for slightly different distance(s).

c. Source: DIRS 101486-Bauer et al. (1996, pp. 542 and 543 with corridor map overlay).

d. Source: DIRS 103406-NDWP (1992, pp. 21 to 25), except hydrographic areas 225 through 230 for which the source is DIRS 147766-Thiel (1999, pp. 6 to 12).

e. To convert acre-feet to cubic meters, multiply by 1,233.49.

3.2.2.1.4 *Biological Resources and Soils*

3.2.2.1.4.1 Biological Resources. The following sections describe biological resources along each of the candidate rail corridors. These environments include habitat types and springs and riparian areas located in a 400-meter (1,300-foot)-wide corridor along each route. Springs and riparian areas are important because they provide habitat for large numbers of plants, animals, and insects. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, all).

Caliente. From the beginning of the corridor at Caliente to Mud Lake, the Caliente Corridor crosses Meadow, Dry Lake, Coal, Garden, Sand Spring, Railroad, Reveille, Stone Cabin, and Ralston Valleys. From Mud Lake, the corridor crosses Stonewall and Sarcobatus flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. The valleys and flats along the corridor range in elevation from 900 to 1,800 meters (3,000 to 5,900 feet). The corridor also crosses through passes or foothills of several mountain ranges including the Highland, Seaman, Golden Gate, Worthington, and Kawich mountain ranges at elevations ranging from 1,600 to 1,900 meters (5,200 to 6,200 feet). The Caliente Corridor is in the southern Great Basin from its beginning at Caliente to near Beatty Wash. The land cover types along this portion of the corridor include salt desert scrub (60 percent) and sagebrush (33 percent). South of Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-22). Table 3-41 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Caliente Corridor. Unless specifically identified otherwise, the text does not describe resources along the corridor variations (that is, options and alternates).

The only resident threatened or endangered species in the Caliente Corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in this area is low in relation to other areas in the range of the species in Nevada (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). Southwestern willow flycatchers *(Empidonax traillii extimus)*, an endangered species, have been observed in dense stands of riparian vegetation in Lincoln County, but there is no suitable habitat for this species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

The Railroad Valley springfish (*Crenichthys nevadae*), which is Federally threatened and State protected (Nevada Administrative Code 503.067) occurs in Warm Springs about 3 kilometers (1.9 miles) north of the corridor in Hot Creek Valley (DIRS 103261-FWS 1996, all).

Three other species classified as sensitive by the Bureau of Land Management occur in the corridor. Unnamed subspecies of the Meadow Valley Wash speckled dace (*Rhinichthys osculus* ssp.) and Meadow Valley Wash desert sucker (*Catostomus clarki* ssp. 2) have been found in Meadow Valley Wash north of Caliente. In the Beatty area, the Nevada sanddune beardtongue (*Penstemon arenarius*) has been found on sandy soils 10 kilometers (6 miles) north of Springdale. Though not listed in the table, a number of bats classified as sensitive by the BLM also may occur along the corridor and the southern end of the corridor is in the range of the chuckwalla (*Sauromalus obesis*).

The Caliente Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 101523-BLM 1994, Maps 9 through 13). The corridor crosses bighorn sheep (*Ovis canadensis*) habitat west of Goldfield near Stonewall Mountain. It also crosses mule deer use areas in or near the Chief/Delamar, Worthington, Quin Canyon, Reveille, and Kawich mountain ranges. The corridor crosses pronghorn antelope (*Antilocapra americana*) habitat in the Railroad/Reveille, Sandspring, Stone Cabin, and Ralston Valleys; Ralston Range; and north of Goldfield. Parts of Meadow Valley Wash north of Caliente are classified as waterfowl and quail habitat, and the corridor crosses another area classified as quail habitat at the north end of the Chief Range.

At least four springs or groups of springs and three streams or riparian areas are within 0.4 kilometer (0.25 mile) of the corridor (DIRS 104593-CRWMS M&O 1999, Appendix E). These might be wetlands or other waters of the United States, as defined in the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Black Spring is near the corridor at the north end of the Kawich Range and an unnamed spring is near the corridor at the north end of the North Pahroc Range. A series of springs is in the corridor near the Amargosa River in Oasis Valley. The corridor crosses the Meadow Valley Wash south of Panaca. The corridor also crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 10 kilometers (6 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock

Table 3-41. Biological resources in or near the Caliente Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Caliente rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Railroad Valley springfish		1
Sensitive species or habitat		
Amargosa toad		5
Eastwood milkvetch		1
Fringed myotis		1
Funeral Mountain milkvetch		1
Hawk nesting area		1
Meadow Valley Wash desert sucker	1	
Meadow Valley Wash speckled dace	1	
Needle Mountain milkvetch		3
Nevada Sanddune beardtongue	1	1
Oasis Valley speckled dace		2
Oasis Valley springsnail		1
Game habitat		
Bighorn–year round	1	2
Mule deer–winter use	2	
Mule deer–summer use		1
Mule deer–year round	3	1
Pronghorn–year round	6	
Quail–crucial	1	
Quail-year round	1	
Waterfowl–crucial	1	
Springs or groups of springs	4[e]	24[f]
Riparian areas	3	1
Herd Management Units	8	
Caliente Option[g]		
Sensitive species		
Welch's catseye		1
Springs or groups of springs	1	4[f]
Crestline Option[g]		
Sensitive species		
Needle Mountain milkvetch		3
Game habitat		
Bighorn sheep–crucial		1
Mule deer–crucial		1
White River Alternate[g]		
Sensitive species		
Pygmy rabbit		1
Welch's catseye		1
Garden Valley Alternate[g]		
Sensitive species		
Welch's catseye		1
Goldfield Alternate[g]		
Springs or groups of springs		2[f]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix E, pp. E-1 to E-12).
b. There are no biological resources unique to the Mud Lake, Bonnie Claire, Oasis Valley, or Beatty Wash Alternates.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
g. Only resources unique to this alignment variation are listed.

waterholes. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management (DIRS 101523-BLM 1994, Maps 14 and 15). The corridor also crosses a number of *ephemeral* streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. Four of the variations (Crestline Option, Caliente Option, Goldfield Alternate, and Oasis Valley Alternate) along the Caliente Corridor would affect the number of, or distance to, associated water resources. Using the Crestline Option, Caliente Option, or Goldfield Alternate would add one spring within 0.4 kilometer (0.25 mile) of the corridor. The Oasis Alternate is close to the same water resources as the corresponding portion of the rail corridor, but it would be farther away from two groups of springs identified near the Amargosa River.

The Caliente Corridor also crosses eight Bureau of Land Management-designated wild horse or wild horse and burro herd management areas (DIRS 101504-BLM 1979, pp. 2-26 through 2-35; DIRS 101523-BLM 1994, Maps 18 and 19). From the beginning of the corridor to Sand Spring Valley, the corridor passes through herd management areas in the Cedar and Chief Ranges. From Sand Spring Valley to Mud Lake, the corridor crosses the Saulsbury, Reveille, and Stone Cabin herd management areas, and from Mud Lake to Yucca Mountain the route crosses the Goldfield, Stonewall, and Bullfrog herd management areas.

Carlin. The Carlin Corridor crosses Crescent and Grass Valleys, then passes through Big Smoky Valley to Mud Lake. From Mud Lake, the corridor crosses Stonewall and Sarcobatus Flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. Elevations along the route range from 900 to 2,200 meters (3,000 to 7,200 feet).

The Carlin Corridor is in the Great Basin from its start in Beowawe to near Beatty Wash. Land cover types along this portion of the corridor are dominated by salt desert scrub (57 percent), sagebrush (28 percent), and greasewood (7 percent). At Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-24). Table 3-42 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Carlin Corridor (without options or alternates) unless specifically identified otherwise.

The only resident threatened or endangered species in the Carlin Corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in the region is low (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411).

Three other species classified as sensitive by the Bureau of Land Management or as protected by Nevada occur along the Carlin Corridor. A ferruginous hawk (*Buteo regalis*) (also classified as protected by Nevada) nesting area is east of Mount Callaghan. The San Antonio pocket gopher (*Thomomys umbrinus curtatus*) has been found in Big Smoky Valley northwest of the San Antonio Mountains. The Nevada sand dune beardtongue has been found in sandy soils 10 kilometers (6 miles) north of Springdale. A number of bats classified as sensitive by the Bureau of Land Management might occur along the corridor, and the southern end of the corridor is in the range of the chuckwalla.

The Carlin Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 103077-BLM 1983, Map 3-1; DIRS 101523-BLM 1994, Maps 9 to 13; DIRS 104593-CRWMS M&O 1999, p. 3-25). The corridor crosses an area designated as sage grouse (*Centrocercus urophasianus*) habitat in western Grass Valley and another at the southeast end of Rye Patch Canyon. The corridor enters pronghorn antelope habitat north of U.S. Highway 50 near Rye Patch Canyon, along most of Big Smoky Valley, and from Mud Lake to Stonewall Mountain. The corridor crosses mule deer habitat on the west side of Grass Valley and bighorn sheep habitat east of Goldfield**.**

Three springs, five riparian areas, and one reservoir are within 0.4 kilometer (0.25 mile) of the Carlin corridor (DIRS 104593-CRWMS M&O 1999, Appendix F). These areas might be wetlands or other waters of the United States, as defined by the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Rye Patch Spring is on the edge of the corridor at the south end of the Simpson Park Mountains. A series of springs is in the corridor near the Amargosa River in Oasis Valley. Seyler Reservoir is less than 0.3 kilometer (0.2 mile) from the corridor in the south end of Big Smoky Valley. Three of the riparian areas (Skull and Ox Corral Creeks, and Rye Patch Canyon) are along the section of the route between Beowawe and Austin at the south end of Grass Valley. Ox Corral Creek, at the south end of Grass Valley, is ephemeral and has little or no riparian vegetation where the route crosses it. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management. This corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. Five of the variations (Oasis Valley Alternate, Steiner Creek Alternate, Rye Patch Alternate, Monitor Valley Option, and Goldfield Alternate) would affect the number of, or distance to Carlin Corridor water resources. Changes associated with the Oasis Valley and Goldfield Alternates were covered above in the Caliente Corridor discussion. The Rye Patch Alternate would involve no changes to water resources identified in, or within 0.4 kilometer of the rail corridor, but would parallel the riparian area in Rye Patch Canyon rather than cross it. The Steiner Creek Alternate would avoid two riparian areas, but another two would be within this variation. The Monitor Valley Option would represent a major change in the corridor, but with respect to water resources within 0.4 kilometer, it would avoid only Seyler Reservoir and would add a designated riparian area northwest of Belmont in its stead.

Table 3-42. Biological resources in or near the Carlin Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Carlin rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Sensitive species		
Amargosa toad		5
Big Smoky Valley speckled dace		1
Crescent Dune aegialian scarab		1
Eastwood milkvetch		1
Ferruginous hawk (nesting area)	1	2
Fringed myotis		1
Funeral Mountain milkvetch		1
Nevada Sanddune beardtongue	1	1
Oasis Valley speckled dace		2
Oasis Valley springsnail		1
Pygmy rabbit		1
San Antonio pocket gopher	1	
Game habitat		
Bighorn–year round	1	2
Mule deer–spring	1	3
Mule deer–summer		3
Mule deer–winter		2
Mule deer–year round		3
Pronghorn–summer	1	
Pronghorn–year round	2	
Sage grouse nesting area		1
Sage grouse strutting ground	2	3
Waterfowl		
Springs or groups of springs	3[e]	60[f]
Riparian areas	5	7
Herd Management Units	6	
Wood Spring Canyon Alternate[g]		
Game habitat		
Mule deer–summer		1
Steiner Creek Alternate[g]		
Springs or groups of springs		3[f]
Riparian areas	2	
Rye Patch Alternate[g]		
Springs or groups of springs		1[f]
Monitor Valley Option[g]		
Sensitive species		
Eastwood milkvetch		1
Pygmy rabbit		1
Speckled dace		1
Game habitat		
Elk	1	
Mule deer–spring	1	
Mule deer–winter		3
Pronghorn–winter	1	
Pronghorn–year round	1	
Sage grouse	2	5
Sage grouse–nesting	1	2
Sage grouse–strutting	1	1
Springs or groups of springs		19[f]
Riparian areas	1	5
Herd Management Units	2	
Goldfield Alternate[g]		
Springs or groups of springs	1	1[e]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix F, pp. F-1 to F-16).
b. There are no biological resources unique to the Crescent Valley, Mud Lake, Bonnie Claire, Oasis Valley, or Beatty Wash Alternates.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
g. Only resources unique to this alignment variation are listed.

The corridor crosses two wild horse or wild horse and burro herd management areas between Beowawe and Austin (Mount Callaghan and Bald Mountain), one in Big Smoky Valley (Hickison) and three between Mud Lake and Yucca Mountain (Goldfield, Stonewall, and Bullfrog) (DIRS 103077-BLM 1983, Map 2-4; DIRS 101523-BLM 1994, Maps 18 and 19).

Caliente-Chalk Mountain. The Caliente-Chalk Mountain Corridor begins near Caliente and is identical to the Caliente Corridor from Caliente to Sand Spring Valley, crossing Meadow, Dry Lake, Coal, and Garden Valleys at elevations ranging from 1,400 to 1,600 meters (4,600 to 5,200 feet). This portion of the corridor also crosses through passes or foothills of the Highland, Seaman, Golden Gate, and Worthington mountain ranges at elevations of 1,500 to 1,800 meters (4,900 to 5,900 feet). After splitting from the Caliente Corridor, the Caliente-Chalk Mountain Corridor proceeds south through Sand Spring and Emigrant Valleys, over Groom Pass, and through Yucca and Jackass Flats to Yucca Mountain. The elevation along this portion of the route ranges from approximately 1,100 to 1,700 meters (3,600 to 5,600 feet).

Predominant land cover types between Caliente and Sand Spring Valley include sagebrush (50 percent) and salt desert scrub (47 percent). The vegetation along the route from Sand Spring Valley to Yucca Flat is typical of the southern portion of the Great Basin. From Yucca Flat to Yucca Mountain, the corridor passes through a zone of transition between the Mojave and Great Basin deserts. The predominant land cover types from Sand Spring Valley to the Yucca Mountain site are blackbrush (50 percent), salt desert

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scrub (31 percent), and sagebrush (9 percent). Table 3-43 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Caliente-Chalk Mountain Corridor (without variations) unless specifically identified otherwise.

Table 3-43. Biological resources in or near the Caliente-Chalk Mountain Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Caliente-Chalk Mountain rail corridor		
Threatened or endangered species		
Desert tortoise		
Sensitive species		
Beatley's scorpionweed		17
Funeral Mountain milkvetch		1
Hawk nesting area		1
Largeflower suncup	1	18
Long-legged myotis		1
Meadow Valley Wash desert sucker	1	
Meadow Valley Wash speckled dace	1	
Needle Mountain milkvetch		3
Oasis Valley springsnail		1
Ripley's springparsley	1	1
Game habitat		
Mule deer–winter	1	
Mule deer–summer		1
Mule deer–year round	2	
Pronghorn–year round	1	
Quail–crucial	1	
Quail–year round	1	
Waterfowl–crucial	1	
Springs or groups of springs	1[e]	14[f]
Riparian areas	2	
Herd Management Units	2	
Mercury Highway Option[g]		
Sensitive species		
Hilend's bedstraw		2
Largeflower suncup		2
Ripley's springparsley	2	6
Springs or groups of springs		2[f]
Topopah Option[g]		
Sensitive species		
Clokey's egg milkvetch		2
Hilend's bedstraw		3
Paiute beardtongue		4
Ripley's springparsley		2
Springs or groups of springs		3[f]
Mine Mountain Alternate[g]		
Sensitive species		
Funeral Mountain milkvetch		4
Largeflower suncup		2
Paiute beardtongue		2
Springs or groups of springs		1[f]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix G, pp. G-1 to G-9).
b. There are no biological resources unique to the Area 4 Alternate. Biological resources for the Crestline and Caliente Options can be found in Table 3-41 for the Caliente Corridor.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Only resources unique to this alignment variation are listed.

The only resident threatened or endangered species in the Caliente-Chalk Mountain Corridor is the desert tortoise, which occurs on the Nevada Test Site south of Yucca Flat. This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance is low (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). Southwestern willow flycatchers, an endangered species, have been observed in dense stands of riparian vegetation in Lincoln County, but there is no suitable habitat for this species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

Four species classified as sensitive by the Bureau of Land Management have been found in the corridor. Unnamed subspecies of the Meadow Valley Wash speckled dace and Meadow Valley Wash desert sucker have been found in Meadow Valley Wash. Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) has been reported between Sand Spring Valley and Yucca Mountain in Yucca Flat. The largeflower suncup (*Camissonia megalantha*) has been found in the corridor at three locations in Yucca Flat. Bats classified as sensitive by the Bureau of Land Management also may occur near the corridor. Chuckwalla may occur in suitable habitat on the Nevada Test Site.

The Caliente-Chalk Mountain Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 101504-BLM 1979, pp. 2-26 through 2-35; DIRS 101523-BLM 1994, Maps 9, 10, and 11). The corridor crosses mule deer use areas in or near the Chief and Delamar ranges, Worthington and Quinn Canyon ranges and north of Groom Pass. The corridor crosses pronghorn habitat in Sand Spring and Emigrant Valleys. Parts of Meadow Valley north of Caliente are classified as waterfowl and quail habitat and the corridor crosses another area classified as quail habitat at the north end of the Chief Range.

At least one spring or group of springs and two streams occur within 0.4 kilometer (0.25 mile) of the corridor. These areas might be classified as wetlands or other waters of the United States (DIRS 104593-CRWMS M&O 1999, p. 3-27), as defined in the Clean Water Act, although no formal wetlands delineation has been conducted. An unnamed spring is near the corridor at the north end of the North Pahroc Range. The corridor crosses Meadow Valley Wash south of Panaca. The corridor crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 10 kilometers (6 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. This corridor also crosses a number of ephemeral streams or washes that might be classified as waters of the United States. Two of the variations (Crestline Option and Caliente Option) would affect the number of or distance to, water resources within a 0.4 kilometer (0.25 mile) of the Caliente-Chalk Mountain Corridor. Changes in the list of nearby water resources for both of these options were covered above in the Caliente Corridor discussion.

The Caliente-Chalk Mountain Corridor passes through two wild horse or wild horse and burro herd management areas (DIRS 101504-BLM 1979, pp. 2-42 and 2-43; DIRS 101523-BLM 1994, Maps 18 and 19) in the Cedar Mountains south of Panaca and in the Chief Range west of Panaca.

Jean. The Jean Corridor starts in Ivanpah Valley north of Jean and proceeds west of Wilson Pass to the Pahrump Valley. The corridor continues to the Yucca Mountain site through Pahrump Valley and across the Amargosa Desert and Jackass Flats. This corridor is in the Mojave Desert, with elevations ranging from about 850 to 1,500 meters (2,800 to 4,900 feet).

The predominant land cover types in the corridor are creosote-bursage (59 percent), Mojave mixed scrub (21 percent), and blackbrush (18 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-28). Table 3-44 lists the biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Jean Corridor (without alternates) unless specifically identified otherwise.

The only resident threatened or endangered species in the Jean Corridor is the desert tortoise. The entire corridor is in the range of this species (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). Along most of the corridor, especially the western portions from Pahrump to Yucca Mountain, the abundance of desert tortoises is low (DIRS 101840-Karl 1980, pp. 75 to 87; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). However, some areas crossed by the corridor in Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have a higher abundance of tortoises (DIRS 101521-BLM 1992, Map 3-13). The corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

One location of each of two subspecies of the pinto beardtongue (*Penstemon bicolor bicolor* and *P.b. roseus),* which is classified as sensitive by the Bureau of Land Management, is in the first 5 kilometers (3 miles) of the corridor near Jean. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters (*Heloderma suspectus cinctum*), and a number of bat species classified as sensitive probably occur there in suitable habitat.

The Jean Corridor crosses several areas the Bureau of Land Management designates as game habitat (DIRS 103079-BLM 1998, Maps 3-7, 3-8, and 3-9). The corridor crosses chukar habitat north of Goodsprings, and quail habitat northwest of Wilson Pass, east of Pahrump, and northwest of Johnnie. The corridor crosses mule deer winter habitat around Wilson Pass and north of Pahrump. The southern edge of bighorn sheep winter range is crossed in the southern Bird Spring Mountains and crucial bighorn habitat is crossed around Wilson Pass. The corridor also crosses a bighorn sheep migration route between the Bird Springs and Spring Mountains and a potential migration corridor from winter range in the Devils Hole Hills to historic but currently unoccupied habitat at the west end of the Spring Mountains.

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Table 3-44. Biological resources in or near the Jean Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Jean rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Sensitive species		
Allen's big-eared bat		1
Death Valley beardtongue		3
Desert bearpoppy		3
Fringed myotis		1
Gila monster		1
Long-legged myotis		1
Oasis Valley springsnail		1
Pinto beardtongue	2	18
Redheaded sphecid wasp		1
Sheep fleabane		1
Spring Mountain milkvetch		2
Townsend's big-eared bat		1
White-margined beardtongue		5
Wolly sage		1
Yuma myotis		1
Game habitat		
Bighorn sheep–crucial	1	1
Bighorn sheep–migration corridor	2	
Bighorn sheep–winter	1	7
Chukar–crucial	1	
Mule deer–summer crucial		2
Mule deer–winter	2	2
Quail–crucial	3	4
Springs or groups of springs		11[e]
Herd Management Units	3	
Stateline Pass Option[f]		
Sensitive species		
White-margined beardtongue		1
Pinto beardtongue		1
Desert bearpoppy		7
Rusby's globemallow		1
Pahrump Valley buckwheat		3
Game habitat		
Bighorn sheep–winter	1	
Quail–crucial		2

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix H, pp. H-1 to H-9).
b. There are no biological resources unique to the North Pahrump Valley Alternate.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
f. Only resources unique to this alignment variation are listed.

There are no springs, perennial streams, or riparian areas within 0.4 kilometer (0.25 mile) of this corridor or its variations. The corridor crosses a number of ephemeral washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

There are three wild horse and burro herd management areas in the corridor (DIRS 103079-BLM 1998, Map 2-1). The Red Rock herd management area is southeast of the Spring Mountains and the Wheeler Pass and Johnnie herd management areas are west of the Spring Mountains.

Valley Modified. The Valley Modified Corridor begins in the northeastern corner of the Las Vegas Valley, crosses the northern edge of the valley south of the Las Vegas Range, and continues northwest toward Indian Springs. The route continues across the southern portion of Three Lakes and Indian Springs Valleys to the Nevada Test Site and passes through Mercury Valley, Rock Valley, and Jackass Flats to the Yucca Mountain site. The corridor ranges in elevation from approximately 700 to 1,100 meters (2,300 to 3,600 feet).

This route is in the Mojave Desert and the predominant land cover types are creosote-bursage (79 percent) and Mojave mixed scrub (16 percent; DIRS 104593-CRWMS M&O 1999, p. 3-29). Table 3-45 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Valley Modified Corridor (without alternatives) unless specifically identified otherwise.

The only resident threatened or endangered species in the Valley Modified Corridor is the desert tortoise. The entire corridor is in the range of this species (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). In general, the abundance of tortoises along this corridor through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). This corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95). The razorback sucker (*Xyrauchen texanus*), classified as threatened under the

Table 3-45. Biological resources in or near the Valley Modified Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Valley Modified rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Pahrump poolfish		2
Razorback sucker		1
Sensitive species		
Beatley's scorpionweed		1
California bearpoppy		17
Death Valley beardtongue		2
Desert bearpoppy		11
Largeflower suncup		3
Mojave milkvetch		1
Parish's scorpionweed	3	6
Pinto beardtongue		2
Ripley's springparsley	1	1
Townsend's big-eared bat		1
White-margined beardtongue		1
Game habitat		
Bighorn sheep–crucial		1
Bighorn sheep–winter		3
Mule deer–winter		1
Quail–crucial		2
Springs or groups of springs		3[e]
Indian Hills Alternate[f]		
Sensitive species		
Desert bearpoppy		1
Mojave milkvetch		4
Herd Management Units	1	

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix I, pp. I-1 to I-6).
b. There are no biological resources unique to the Sheep Mountain Alternate or Valley Connector.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
f. Only resources unique to this alignment variation are listed.

Endangered Species Act and as protected under Nevada Administrative Code, have been introduced into ponds at Floyd Lamb State Park, 4.2 kilometers (2.6 miles) south of the corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29). Refuge populations of the Pahrump poolfish (*Empetrichthys latos latos*), classified as endangered under the Endangered Species Act and Nevada Administrative Code, have been introduced into ponds in Floyd Lamb State Park and into the outflow of Corn Creek Springs, 4.5 kilometers (2.8 miles) northeast of the corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29).

Two other species classified as sensitive by the Bureau of Land Management occur in the corridor. Three populations of Parish's scorpionweed (*Phacelia parishii*) and a population of Ripley's springparsley have been reported on the Nevada Test Site in Rock Valley. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters, and a number of bat species probably occur there in suitable habitat.

There are no herd management areas, Areas of Critical Environmental Concern, or designated game habitat in the Valley Modified Corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29; DIRS 103079-BLM 1998, Maps 3-7, 3-8, and 3-9). No springs or riparian areas occur within 0.4 kilometer (0.25 mile) of this rail corridor or its variations. This corridor crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

3.2.2.1.4.2 Soils. Soil surveys have been performed and documented throughout much of the United States, including portions of Nevada, by the U.S. Department of Agriculture. Further, the Department of Agriculture has undertaken several efforts to compile this soil survey data into computerized databases for use by government agencies and the general public. One of these databases, the State Soil Geographic database, was developed by generalizing more detailed soil survey data; its purpose is to support planning on the State and multicounty level (DIRS 154246-USDA 1994, pp. 1 and 2). The Yucca Mountain

Project has queried the database for information on soils along the rail corridors. Though the database presents generalized, or higher level information, it still contains massive amounts of data, much more than can be presented in this EIS. However, DOE selected several soil characteristics with potential for environmental impact implications for presentation here to indicate the types of soil along the corridors. One of the database elements selected was soil areas designated as prime farmland. Prime farmlands are defined as lands that have the best combination of physical and chemical characteristics needed to economically produce sustained high-yield agricultural crops [7 CFR 657.5(a)]. Based on the query of the State Soil Geographic database, there are no soils classified as prime farmlands in the rail corridors, including the option and alternate segments (DIRS 155600-Sorensen 2001, p. 2).

DOE also queried the database for other codes representing soil attributes that could be of concern from an environmental perspective and that would need to be considered during the design and construction of a new branch rail line. The query was made by overlaying the rail corridor locations on the soil units in the database and the result was the identification, by corridor segment, of whether the identified attribute might be present in the area in or around the segment. The selected soil attributes in this query are termed “shrink swell,” “erodes easily,” “unstable fill,” and “blowing soil.” Each of these attributes not only represents potential environmental and construction concerns, but is associated with physical characteristics of soil. The following paragraphs describe these attributes.

The *shrink swell* attribute is a gauge of how much the volume of a soil changes when it is wet compared to when it is dry. In the State Soil Geographic database, any soil that swells less than 3 percent when wet is considered to have “low” limitations with respect to its use in construction; 3 to 6 percent is considered to present “moderate” limitations and greater than 6 percent has “high” limitations [DIRS 155602-USDA 2001, Part 620.05(a)(2) and Table 620-2]. Querying the database for the shrink swell code identifies (but does not distinguish) soils with moderate or high limitations. The purpose of these limitations is not to indicate that construction cannot or should not be performed in such soils, but rather that the design and construction plans need to account for that soil characteristic. A soil’s potential for volume change with loss or gain of moisture varies with the amount and type of clay minerals it contains. In general, more clay in the soil indicates a greater volume change.

The *erodes easily* attribute is a measure of the susceptibility of bare soil to be detached and moved by water. It is based on a factor (designated as “K”) used in the commonly employed Universal Soil Loss Equation [DIRS 155602-USDA 2001, Part 620.04 and 620.06(f)(9)]. Measurements on standardized plots are used to determine experimentally values for K, which range from 0.02 to 0.64. Other factors in the equation being equal, a higher K value indicates more susceptibility to erosion by water. The main properties affecting this attribute are soil texture, organic material structure, and permeability. In general, clay soils have low K values because they are resistant to detachment, and sandy soils have low values because they have high infiltration rates (reduced runoff) and particles that erode are not easily transported. Silt loam soils have moderate to high K values. Silt soils have the highest values because they readily form crusts that promote runoff and the particles are easily detached and transported (DIRS 155601-USDA 2001, all). Querying the database for the *erodes easily* code identifies soils with K values greater than 0.35. These are soils with fair to poor erosion characteristics when disturbed and that probably contain relatively high amounts of loams and silts.

The *unstable fill* attribute is a measure of a soil’s tendency to move when it is wet or loaded, or both. Stable soils are generally not subject to mass movement under these conditions, and moderately stable soils can involve mass movement when a moderate disturbance provides the initiating action. In unstable soils, slight disturbances can result in mass movement when soil is wet or loaded [DIRS 155602-USDA 2001, Part 620.12(a)(1) and Table 620-37]. Soils identified in the database with the *unstable fill* code are those likely to be moderately stable or unstable when used as fill.

The *blowing soil* attribute is based on groupings used during soil surveys to classify the susceptibility of soil to wind erosion. This classification method uses eight groupings. Soils assigned to group 1 are the most susceptible to wind erosion and those assigned to group 8 are the least susceptible. Descriptions of soils in the groupings range from sands to coarse fragments not susceptible to wind erosion (DIRS 155602-USDA 2001, Part 618.72 and Exhibit 618-16). Querying the database for the blowing soil code identifies soils with wind erodibility groups of 1 or 2 [DIRS 155602-USDA 2001, Part 620.06(f)(9) and Table 620-11]. The definitions of these two groups are as follows:

- Group 1 - Coarse sands, sands, fine sands, and very fine sands
- Group 2 - Loamy coarse sands, loamy sands, loamy fine sands, loamy very fine sands, ash material and sapric (fine, decomposed, organic muck) soil material

The blowing soil attribute identifies areas where fine textured, sandy materials probably predominate and where uncontrolled soil disturbance could result in increased wind erosion.

The following paragraphs discuss the results of the State Soil Geographic database query for the four identified soil attributes by rail corridor. In general terms, the corridors that approach Yucca Mountain from the north (that is, the Caliente, Carlin, and Caliente-Chalk Mountain Corridors) encounter relatively high percentages of soils with *shrink swell*, *erodes easily*, and *blowing soil* characteristics. The corridors that approach Yucca Mountain from the south (that is, the Jean and Valley Modified Corridors) encounter relatively high percentages of soils with only two of those characteristics (that is, *shrink swell* and *blowing soil*). None of the corridors would have high percentages of *unstable fill*, though such soil is present in about 10 percent of the Jean Corridor. The corridor-specific soil information presented in the following paragraphs does not represent detailed soil survey data, but does provide insight into the soil characteristics and potential environmental aspects that would have to be considered during the engineering and design of a branch rail line. Should a decision be made to select one of the rail corridors for transportation of materials to Yucca Mountain, DOE would perform soil surveys of the selected corridor to collect detailed information on the environmental and engineering characteristics of the soils that would be encountered.

Caliente Corridor. Table 3-46 lists the percentage of the Caliente Corridor that crosses soils with the four attributes described in this section. The percentage is the portion of the corridor in which the identified soil attribute could present a concern or limitation for the construction of a rail line. The *shrink swell*, *erodes easily*, and *blowing soils* attributes are prevalent along this corridor. Soils with shrink swell and erodes easily attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, pp. 15 and 16). The *blowing soil* attribute is associated with soils scattered heavily throughout the State (DIRS 155600-Sorensen 2001, p. 18). The corridor crosses no soil areas identified with the *unstable fill* attribute. As indicated in the table, the use of any of the alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 3 percent.

Table 3-46. Percentage of the Caliente Corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Caliente Corridor	61	69	0	81
Change with any other alternate/option	± 3	± 3	± 0	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Carlin Corridor. Table 3-47 lists the percentage of the Carlin Corridor that crosses soils with the four attributes described in this section. The *shrink swell, erodes easily*, and *blowing soils* attributes are prevalent along this corridor. Soils with *shrink swell* and *erodes easily* attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, p. 15 and 16). The *blowing soil* attribute is associated with soils scattered throughout the State (DIRS 155600-Sorensen 2001, p. 18). The Carlin Corridor would cross no soil areas identified with the *unstable fill* attribute. If the Monitor Valley option was used, the soil attribute percentages would change little with the exception of the *shrink swell* attribute, which would increase by

Table 3-47. Percentage of the Carlin Corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Carlin Corridor	56	69	0	88
With Monitor Valley Option	76	69	0	84
Change with any other alternate/option	± 2	± 3	± 0	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

about 20 percent. As indicated in the table, the use of any of the other alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 3 percent.

Caliente-Chalk Mountain. Table 3-48 presents the percentage of the Caliente-Chalk Mountain rail corridor that would cross soils with the four attributes described in this section. As can be seen in the table, the *shrink swell, erodes easily,* and *blowing soils* attributes are prevalent along this rail corridor as they are for the other two corridors that would approach the site from the north. Soils with *shrink swell* and *erodes easily* attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, pp. 15 and 16). The *blowing soil* attribute is associated with soils scattered heavily throughout the state (DIRS 155600-Sorensen 2001, p. 18). The Caliente-Chalk Mountain rail corridor would cross no soil areas identified with the *unstable fill* attribute. As shown in the table, use of any one of the other alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 4 percent.

Table 3-48. Percentage of the Caliente-Chalk Mountain rail corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Caliente-Chalk Mountain rail corridor	52	75	0	86
Change with any single alternate/option	± 4	± 3	± 0	± 2

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Jean Corridor. Table 3-49 lists the percentage of the Jean Corridor that would cross soils with the four attributes described in this section. The *shrink swell* and *blowing soils* attributes are prevalent along this corridor even though these soils occur only in scattered locations in southern Nevada (DIRS 155600-Sorensen 2001, pp. 16 and 18). A small amount of this corridor passes through soil areas with *erodes easily* and *unstable fill* attributes. As indicated in the table, if DOE used the Stateline Pass Alternate, the percentage of the corridor crossing soils with *erodes easily* and *blowing soil* attributes would increase about 10 percent for either attribute. Use of the Pahrump Alternate would result in little or no change in the corridor's soil attributes.

Table 3-49. Percentage of the Jean Corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Jean Corridor	89	11	10	77
With Pahrump Valley Alternate	89	11	10	78
With the Stateline Pass Alternate	92	19	11	91

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Valley Modified Corridor. Table 3-50 lists the percentage of the Valley Modified Corridor that crosses soils with the four attributes described in this section. The *shrink swell* and *blowing soils* attributes are prevalent along this corridor, even though these soils occur only in scattered locations in southern Nevada (DIRS 155600-Sorensen 2001, pp. 16 and 18). This corridor would not pass through any significant amount of soil area with *erodes easily* and *unstable fill* attributes. As indicated in the table, if DOE used

Table 3-50. Percentage of the Valley Modified rail corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Valley Modified Corridor	76	0	0	76
With the Indian Hills Alternate	92	0	0	92
Change with any other alternate	± 1	± 0.2	± 0.2	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

the Indian Hills Alternate, the percentage of the corridor crossing soils with *shrink swell* and *blowing soil* attributes would increase about 16 percent for either attribute. Use of either of the other two alternates (Valley Connector or Sheep Mountain) would result in little change in the corridor's soil attributes.

3.2.2.1.5 *Cultural Resources*

The baseline environmental conditions presented in this section focus on the archaeological and historic resources associated with the candidate rail corridors. This section also discusses Native American interests in relation to two of the corridors. Unless otherwise noted, this information is from the *Environmental Baseline File for Archaeological Resources* (DIRS 104997-CRWMS M&O 1999, all). In addition, information from the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all) and *Additional Baseline Cultural Resources Data for the Nevada Transportation Scenario* (DIRS 155826-Nickens and Hartwell 2001, all) were used.

Archaeological and Historic Resources. Based on a records search at the Desert Research Institute in Las Vegas and Reno, the Harry Reid Center at the University of Nevada, Las Vegas, and the Bureau of Land Management Battle Mountain and Elko Offices, archaeological surveys have been conducted in less than 1 percent of the total areas for the Caliente, Jean, and Valley Modified Corridors, less than 3 percent of the total area for the Carlin Corridor, and less than 5 percent of the total area for the Caliente-Chalk Mountain Corridor. The record searches examined each candidate rail corridor, including the variations. Although it is possible to identify areas in a corridor that are most likely to contain cultural resources based on such factors as general land forms and proximity to water, these predictions are highly uncertain prior to corridor selection and the completion of intensive field studies and, therefore, are not included in this EIS.

Initially, archaeological site file searches were completed for larger rail corridors, ranging between 1.6 and 8 kilometers (1 and 5 miles) in total width. More than 2,300 archaeological and historic sites were documented for these wider corridors. The wider corridors used in the initial records searches included all corridor variations. As project plans become more detailed, it was possible to reduce the potential corridor width to a 0.2-kilometer (0.1-mile)-wide buffer zone on either side of the centerline. Records indicate that a number of archaeological sites have been identified along the reduced corridors and that some of these sites are recorded as potentially eligible for nomination to the *National Register of Historic Places*. Table 3-51 summarizes this information. The table also lists potentially eligible sites by type. For conservatism, this group includes sites not yet evaluated for eligibility. The sites recorded but not included in the potentially eligible group represent sites that had no recommendations about eligibility to the National Register.

DOE is implementing the stipulations and forms of a Programmatic Agreement (DIRS 104558-DOE 1988, all) with the Advisory Council on Historic Preservation to address DOE's responsibilities under Sections 106 and 110 of the National Historical Preservation Act and the Council's implementing regulations. Although not a formal signatory to the Agreement, the Nevada State Historic Preservation Officer has the right at any time, upon request, to participate in monitoring DOE compliance with the Programmatic Agreement. In addition, DOE provides annual reports to the Advisory Council on Historic

Table 3-51. Number of previously recorded archaeological sites along candidate rail corridors including variations [based on corridor width of 0.4 kilometer (0.25 mile)].

Category[a]	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Potentially eligible for nomination					
Temporary camps	--[b]	--	3	--	--
Extractive localities	--	--	3	--	--
Processing localities	--	--	--	--	--
Localities	--	1	16	--	--
Caches	--	--	--	--	--
Stations	--	--	--	--	--
Historic sites	--	--	3	--	--
Unknown type	7	20	3	--	7
Total potentially eligible	*7*	*21*	*28*	*0*	*7*
Not evaluated	29	26	6	2	4
Recorded sites (approximate total)	*97*	*110*	*100*	*6*	*19*

a. Section 3.1.6 contains the definitions of site types for potentially eligible for nomination sites (temporary camps, extractive localities, etc.).
b. -- = none identified.

Preservation and the Nevada State Historic Preservation Officer describing the activities conducted by DOE each year to implement the stipulations of the Programmatic Agreement. This report includes a description of DOE coordinations and consultations with Federal and State agencies and Native American tribes concerning historic and culturally significant properties at Yucca Mountain.

DOE will continue to seek input from the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation, and will interact appropriately to meet the reporting and other stipulations of the existing Programmatic Agreement. Because the 1988 Programmatic Agreement primarily covers site characterization activities at the Yucca Mountain site, DOE would negotiate a new programmatic agreement to cover cultural resources requirements for any selected Nevada transportation corridor.

Records and literature reviews reveal the presence of numerous historic properties and districts that one or more of the candidate rail corridors could affect, depending on the route selected. A number of these are linear features that a given corridor would intersect. Table 3-52 lists the more important of these linear properties.

In addition to the linear historic properties, the candidate rail corridors are close to several other historic properties, many of which are already listed on either the *Nevada State Register of Historic Places* or the *National Register of Historic Places*, or are currently unevaluated. Table 3-53 lists the more important properties.

Other potentially important historic properties that could be within rail corridors include elements of many historic mining districts, several historic ranches (especially Crescent, Grass, Big Smoky, and Monitor Valleys), and the World War II Tonopah Army Air Field bombing range. Numerous Cold War-era resources that have been documented at the Nevada Test Site could be affected (for example, Camp Desert Rock).

Native American Interests. Through the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations, Native Americans have noted that, while transportation issues are of extreme interest to them, at present they cannot provide specific comments on any of the Nevada transportation project alternatives (DIRS 102043-AIWS 1998, pp. 4-4 to 4-6) due to the absence of systematic ethnographic studies for any of the proposed project areas.

Table 3-52. Historic period linear cultural resource properties intersected by potential rail corridors and variations.[a]

Property	Rail corridor-variation	National Historic Trail Designation Status[b]
California Emigrant Trail (1840s)	Carlin	Designated *California National Historic Trail.* Segment is designated Low Potential.[c]
Western Pacific Railroad (1907)	Carlin	
Salt Lake to San Francisco Transcontinental Airways Route (1920-1940s) and Parran to Beowawe Cutoff (1928-1929)	Carlin	
Jedidiah Smith Exploration Route (1827)	Carlin - Monitor Valley Option	
John C. Fremont Military Reconnaissance Route (1845-1846)	Carlin - Big Smoky Valley Option	
James Simpson Federal Wagon Road Route Survey (1859)	Carlin and Monitor Valley Options	
Pony Express Trail (1861)	Carlin and Rye Patch Alternates and Monitor Valley Option	Designated *Pony Express National Trail.* Segment is designated High Potential.[c]
Pacific Telegraph Line (1861)	Carlin and Rye Patch Alternate	
Butterfield Overland Mail & Stage Route (1861)	Carlin and Rye Patch Alternate	
Lincoln Highway (1920s)	Carlin and Rye Patch Alternates and Monitor Valley Option	
Tonopah-Goldfield Railroad (1903-1947)	Carlin/Caliente	
Las Vegas and Tonopah Railroad (1905-1918)	Carlin/Caliente Valley Modified and Indian Hills and Sheep Mountain Alternates	
Jayhawker's Emigrant Trail (1849)	Caliente/Caliente-Chalk Mountain	
Old Spanish Trail (1830); later the Mormon Road (after 1850)	Jean and Stateline Pass Option	Under evaluation for designation by Congress as a National Historic Trail
Yellow Pine Mining Company railroad (1911-1934)	Jean	
Las Vegas to Bullfrog Stage Road (1904-1906)	Carlin Valley Modified - Indian Hills Alternate	
Caliente and Pioche Railroad (1907)	Caliente and Caliente and Crestline Options	

a. Source: DIRS 155826-Nickens and Hartwell (2001, pp. 15 and 20 to 25).
b. Those properties showing no status entries are neither designated by Congress as National Historic Trails nor under evaluation for such a status.
c. Trail segments are evaluated for their potential to afford a high-quality recreation experience in a portion of the route having greater than average scenic values or affording an opportunity to vicariously share the experience of the original users of the trail. Evaluations shown here apply to the trail segment intersected by the applicable rail corridor.

Table 3-53. Cultural resource properties close to proposed rail corridors and listed on State or National Registers of historic places.[a]

Property	Rail corridor	Status
Tonopah Multiple Resource Area	Carlin/Caliente	NRHP
Belmont Historic District	Carlin – Monitor Valley Option	NSRHP, NRHP
Goldfield Historic District	Carlin/Caliente and Goldfield Alternates	NRHP
Union Pacific Depot, Caliente	Caliente	NRHP
Smith (Scott) Hotel, Caliente	Caliente	NSRHP
Sedan Crater Area 10, Nevada Test Site	Caliente-Chalk Mountain	NRHP
Goodsprings Mining District	Jean	NSRHP
Tule Springs Archaeological Site	Valley Modified	NSRHP, NRHP
Corn Creek Campsite	Valley Modified	NRHP
Tule Springs Ranch District	Valley Modified	NRHP

a. Source: DIRS 155826-Nickens and Hartwell (2001, Table 6, pp. 17-19).
b. NRHP = *National Register of Historic Places*; NSRHP = *Nevada State Register of Historic Places.*

General concerns for potential transportation-related impacts raised by Native Americans include the following:

- Radioactive and hazardous waste transportation could have an adverse impact along rail or highway routes near existing or planned Native American communities, people, businesses, and resources.

- All of the proposed routes being considered pass through the traditional holy lands of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples.

- Many of these routes correspond or are adjacent to ancient pathways and complex trail systems known to and used by Native American peoples.

- The Consolidated Group of Tribes and Organizations is aware of important culturally sensitive areas, traditional use areas, sacred sites, and other important resources that fall in the proposed transportation project areas, and will present this information when appropriate in the development of the Nevada transportation system.

These general concerns apply to the proposed rail corridors discussed in this section, and the proposed heavy-haul truck route alternatives and intermodal transfer station locations discussed in Section 3.2.2.2.5.

There are three known historic period Native American cemeteries, two in Crescent Valley and one to the south in Grass Valley. One of the Crescent Valley cemeteries is still in use and is about 1.6 kilometers (1 mile) east of the corridor; the other smaller, early historic cemetery is possibly located within the corridor. The Native American cemetery in Grass Valley might also be located within the corridor. In addition, Western Shoshone families use several hot springs in Crescent Valley for ceremonies. Archaeological investigations in Grass Valley have documented the presence of several historic period Western Shoshone villages, many near ranches that employed Native Americans. For example, at the Grass Valley Ranch, which the Carlin route passes, there are six known villages, several of which might be in the Carlin corridor. Late 19th- and 20th-century Native American villages and homes found in association with Euro-American ranches could occur in many of the valleys that the rail corridors pass through. The same might be true at several mining districts that attracted Native Americans with employment opportunities.

Recent Native American field studies (DIRS 156932-AIET 2000, all) have demonstrated the importance of the Wild Horse and Willow Springs areas, which occur on Nellis Air Force Range and Bureau of Land Management lands east of the Town of Goldfield. The combined Carlin-Caliente Corridor passes to the east of the two springs; the Goldfield Alternate passes to the west. The Goldfield Alternate is the closest to either spring, being about 1.2 kilometers (0.7 mile) west of Willow Springs (DIRS 104593-CRWMS M&O 1999, Appendix E, p. E-10).

Native American communities are present near at least two of the candidate rail corridors:

- *Jean.* The Pahrump Paiute Tribe is a non-Federally recognized tribe without a land base. The tribe consists of about 100 Southern Paiute people living in the Pahrump area (see Section 3.1.6.2). Individual members of the tribe live as close as 5 kilometers (3 miles) to the Jean Corridor.

- *Valley Modified.* The Las Vegas Paiute Tribe is a Federally recognized tribe consisting of about 100 people living on two separate tribal parcels in southern Nevada. One parcel near downtown Las Vegas consists of about 73,000 square meters (18 acres) of land with 21 homes, tribal administrative offices, and various tribal businesses. This parcel is about 11 kilometers (7 miles) from the route of the Valley Modified Corridor. The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16 million square meters (4,000 acres) with 12 homes and various business enterprises. This parcel is about 1.6 kilometers (1 mile) from the Valley Modified Corridor.

Congress has assigned trust lands to the Timbisha Shoshone that would directly involve the Carlin and Caliente Corridors. This is the Timbisha Shoshone Tribe Homeland effort, part of which transfers 11 square kilometers (2,800 acres) of Bureau of Land Management land at Scottys Junction to the Secretary of the Interior to hold in trust for the Tribe. This area is within the Tribe's former homeland and several tribal families lived there. The Tribe plans to use this tract for single-family residences and small-scale economic development (DIRS 154121-DOI 2000, Volume I, p. 19). The Bonnie Claire Alternate of both the Carlin and Caliente Corridors passes directly through the tract transferred to the Timbisha Shoshone Tribe.

In addition, private Native American land holdings could be affected along the Carlin corridor. Western Shoshone families own ranches in Crescent Valley, and several allotments were made to Western Shoshone individuals by the U.S. Government from 1919 to 1925 under provisions of the Dawes Allotment Act of 1887. Several of these allotments were in Big Smoky Valley and Monitor Valley.

3.2.2.1.6 *Socioeconomics*

Section 3.1.7 describes the socioeconomic backgrounds of the three counties (Clark, Lincoln, and Nye) most involved in the corridors. The Carlin corridor includes other counties—Esmeralda, Eureka, and Lander—in addition to Nye County. This section contains baseline socioeconomic information for Eureka, Esmeralda, and Lander Counties.

Socioeconomic effects from the construction of a rail line would be small and, for the most part, short-term. Therefore, the socioeconomic information for Esmeralda, Eureka, and Lander Counties is less detailed than the information for the counties in the repository site region of influence in Section 3.1.7.

Population. Section 3.1.7.1 contains population data on Clark, Lincoln, and Nye Counties. This section provides population background for the other counties potentially affected by the Carlin Corridor (Esmeralda, Eureka, and Lander).

The population of Esmeralda County is 100 percent rural. The 1990 Census population for the county was about 1,300 persons. The 2000 population density of the county is somewhat less than 0.3 person per square mile. The estimated Esmeralda County population in 2000 was about 970 (DIRS 155872-Bureau of the Census 2000, County Totals).

The population of Eureka County is 100 percent rural. The 1990 Census population of the county was about 1,500. The estimated population of Eureka County in 2000 was about 1,650 (DIRS 155872-Bureau of the Census 2000, County Totals). The 2000 population density was about 0.4 person per square mile.

The population of Lander County is rural, with a small urbanized population concentrated entirely in Battle Mountain. The 1990 Census population of the county was about 6,300 persons. The estimated population of Lander County in 2000 was about 7,100 (DIRS 155872-Bureau of the Census 2000, County Totals). The county had a 2000 population density of about 1.2 persons per square mile.

Employment. Section 3.1.7.2 contains employment and economic information on Clark, Nye, and Lincoln Counties. Portions of the potential Carlin rail route pass through Esmeralda, Eureka, and Lander Counties. In 2000, Esmeralda, Eureka, and Lander Counties had average labor forces of about 470, 850, and 2,320, respectively, and average unemployment rates of 10.0, 2.6, and 7.7 percent (DIRS 155818-NDETR 2001, all). In 1997, the per capita income of Esmeralda, Eureka, and Lander Counties was about $19,200, $22,000, and $21,000, respectively (DIRS 153928-NDA 2000, all). All three of these counties are small in economic terms.

Housing. Section 3.1.7.4 contains housing data on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are all rural areas. The housing stock of Esmeralda County in 1990 was about 1,000 units, of which about 590 were occupied (DIRS 148097-Bureau of the Census 1998, Esmeralda). There were about 830 units in 2000 (DIRS 155872-Bureau of the Census 2000, all). The housing stock of Eureka County in 1990 was about 820 units, of which about 620 were occupied (DIRS 148097-Bureau of the Census 1998, Eureka). In 2000, there were about 1,000 units (DIRS 155872-Bureau of the Census 2000, Eureka). The housing stock of Lander County in 1990 was about 2,600 housing units, of which about 2,200 were occupied (DIRS 148097-Bureau of the Census 1998, Lander). In 2000, there were about 2,800 units (DIRS 155872-Bureau of the Census 2000, Lander).

Economy. Section 3.1.7.2 contains employment and economic information on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander are very small counties in economic terms. Eureka and Esmeralda Counties derive most of their economic activity from the accommodations and food service industry. Lander County's largest industries are in the retail and wholesale sectors. Like Lincoln County, Esmeralda and Lander have lower per capita incomes than other Nevada counties and chronically high unemployment.

Public Services. Section 3.1.7.5 contains information on public services in Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. County sheriff departments serve Eureka, Esmeralda, and Lander Counties. During the 2000-2001 school term, the Eureka County school district served 305 students, the Lander County district enrolled 1,449 (847 kindergarten through grade 6 and 602 secondary students), and the Esmeralda County school district served 107 students in kindergarten through grade 8. High-school aged students from Esmeralda attended school in Tonopah (Nye County) (DIRS 155820-NDE 2001, "Nevada School Enrollment 2000-2001"). In 1998, Esmeralda had no practicing doctors or dentists, Eureka had a single practicing physician but no dentists, and Lander County had three doctors and two dentists (DIRS 153928-NDA 2000, all).

3.2.2.1.7 *Noise and Vibration*

Most of the proposed rail corridors pass through unpopulated desert with average day-night background sound levels of 22 to 38 A-weighted decibels (dBA). (A-weighted decibels are explained in Section 3.1.9.1.) However, each candidate corridor passes near small rural communities (see Chapter 6, Figures 6-15 through 6-19). Noise levels in rural communities usually range from 40 to 55 dBA. DOE used computerized mapping programs to examine proposed transportation corridors for the presence and proximity to routes that could be designated for the transfer of nuclear material to the Yucca Mountain site. The process involved the examination of computerized maps at very high detail to determine the extent of road grids in communities and major road intersections. The analysis estimated the distance from the proposed rail corridor and the community to determine if the community was in the region of influence for rail transportation.

Caliente. Most of the Caliente Corridor passes through undeveloped Bureau of Land Management land where background noise levels range from 22 to 38 dBA (Table 3-32), influenced primarily by wind. Noise levels of 40 to 55 dBA are present in the rural communities along the corridor including Beatty, Goldfield, Panaca, and Caliente (Table 3-32).

Carlin. The Carlin Corridor, from its origin at Beowawe to its terminus at Yucca Mountain, including the Monitor Valley option and other options south of Tonopah, traverses mostly unpopulated desert. The only town within 1.6 kilometers (1 mile) of the corridor is Hadley at the southern end of Big Smoky Valley (Monitor Valley option). Noise levels of 40 to 55 dBA are present in rural communities near the corridor, including Beatty, Goldfield, Tonopah, Austin, and smaller communities between Tonopah and Battle Mountain (Table 3-32). Occasional noise from military aircraft overflights occurs near the Nellis Air Force Range.

Caliente-Chalk Mountain. Almost half of the 345-kilometer (214-mile) Caliente-Chalk Mountain Corridor is on Nellis Air Force Range or Nevada Test Site land; the remainder is on Bureau on Land Management land. Noise levels of 40 to 55 dBA are present in rural communities along the corridor including Panaca and Caliente (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Jean. The Jean Corridor, with the Stateline option, passes through Bureau of Land Management land and a small section of private land. A large portion of this proposed corridor passes through unpopulated desert. Noise levels of 40 to 55 dBA are present in small communities along the corridor including Amargosa Valley, Goodsprings, Pahrump, and Jean (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Valley Modified. The Valley Modified Corridor, and its various options, begins in the northeast end of the Las Vegas Valley, travels west across Nellis Air Force Base and the southern end of the Desert National Wildlife Range, and then closely parallels U.S. 95 to the vicinity of Mercury (a government installation). Noise levels along stretches of unpopulated desert should range from 22 to 38 dBA, which are typical for a desert environment during calm and windy days (DIRS 101531-Brown-Buntin 1997, p. 7). The corridor would pass 3 kilometers (2 miles) north of Floyd R. Lamb State Park and less than 5 kilometers (3 miles) south of Corn Creek Station, which is part of the Desert National Wildlife Range managed by the Fish and Wildlife Service. Noise levels at the state park and at Corn Creek would probably be only slightly higher than those in an unpopulated desert environment. Noise levels in the northern Las Vegas Valley can be as high as 60 dBA (Table 3-32). Noise levels in Indian Springs, Cactus Springs, and Mercury probably range from 40 to 55 dBA (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Ground Vibration. Railroad construction and the operation of trains transporting materials and nuclear waste in casks have been proposed for several candidate rail corridors. These corridors have been planned to avoid human residences and communities to the extent possible. As a consequence, background levels of ground vibration lack human influence and are small; that is, most likely less than 50 VdB (velocity decibels, a measure of vibration amplitude).

3.2.2.1.8 *Aesthetics*

To assist in the management of public lands under its control, the Bureau of Land Management established land management guidelines based on the visual resources of an area. Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. There are four visual resource classes. Classes I and II are the more highly valued. Class III is moderately valued, and Class IV is of least value. The majority of land in the potential rail corridors is under the jurisdiction of the Bureau of Land Management. The following paragraphs contain aesthetic baseline information for each of the rail corridors. Visual resource classifications described for the rail corridors were obtained from published Bureau of Land Management documents or through conversations with Bureau of Land Management personnel. Scenic quality classifications for lands that would be crossed on the Nevada Test Site were generated by DOE using Bureau of Land Management guidelines. Section 3.1.10 contains more information on the Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (DIRS 105002-CRWMS M&O 1999, all).

Caliente. Section 3.2.2.1.4 describes the environmental setting along the Caliente Corridor. The corridor passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. The corridor crosses mostly Class IV lands, crosses Class III land near Caliente, and crosses or skirts the edges of Class II lands near Caliente and in the Seaman, Reveille and Kawich ranges, the Golden Gate Hills, and the Worthington Mountains. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Carlin. Section 3.2.2.1.4 describes the environmental setting of the Carlin corridor. The corridor passes through four Bureau of Land Management resource areas (Elko, Shoshone-Eureka, Tonopah, and Las Vegas). The route is on Class IV land from its beginning to the Nevada Test Site border. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Caliente-Chalk Mountain. Section 3.2.2.1.4 describes the environmental setting of the Caliente-Chalk Mountain Corridor. The corridor passes through the Caliente and Schell Bureau of Land Management resource areas. The route begins on Class III land east of Caliente, and crosses mostly Class IV land to the border of the Nevada Test Site (Figure 3-31). On the Nevada Test Site the corridor passes through lands with scenic quality Class B or C.

Jean. Section 3.2.2.1.4 describes the environmental setting of the Jean Corridor. The corridor crosses the Las Vegas and the Northern and Eastern Mojave Bureau of Land Management resource areas. The Wilson Pass Option of the corridor passes through Class II land in Goodsprings Valley and the Spring Mountains, but the rest of the route to the west and the Stateline Pass Option cross Class III land. Approximately 10 kilometers (6 miles) of the route crosses lands in California; that area does not have Visual Resource Management class ratings. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Valley Modified. Section 3.2.2.1.4 describes the environmental setting of the Valley Modified Corridor. The corridor crosses the Las Vegas Bureau of Land Management resource area. The entire route to the boundary of the Nevada Test Site crosses Class III land. Lands on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Section 3.2.2.1.1 contains additional information on current land use. Based on these descriptions, all of the candidate rail corridors have been affected to some extent by man. Based on a field survey by DOE, these impacts can be seen from the potential corridors and in detail from the adjacent mountains.

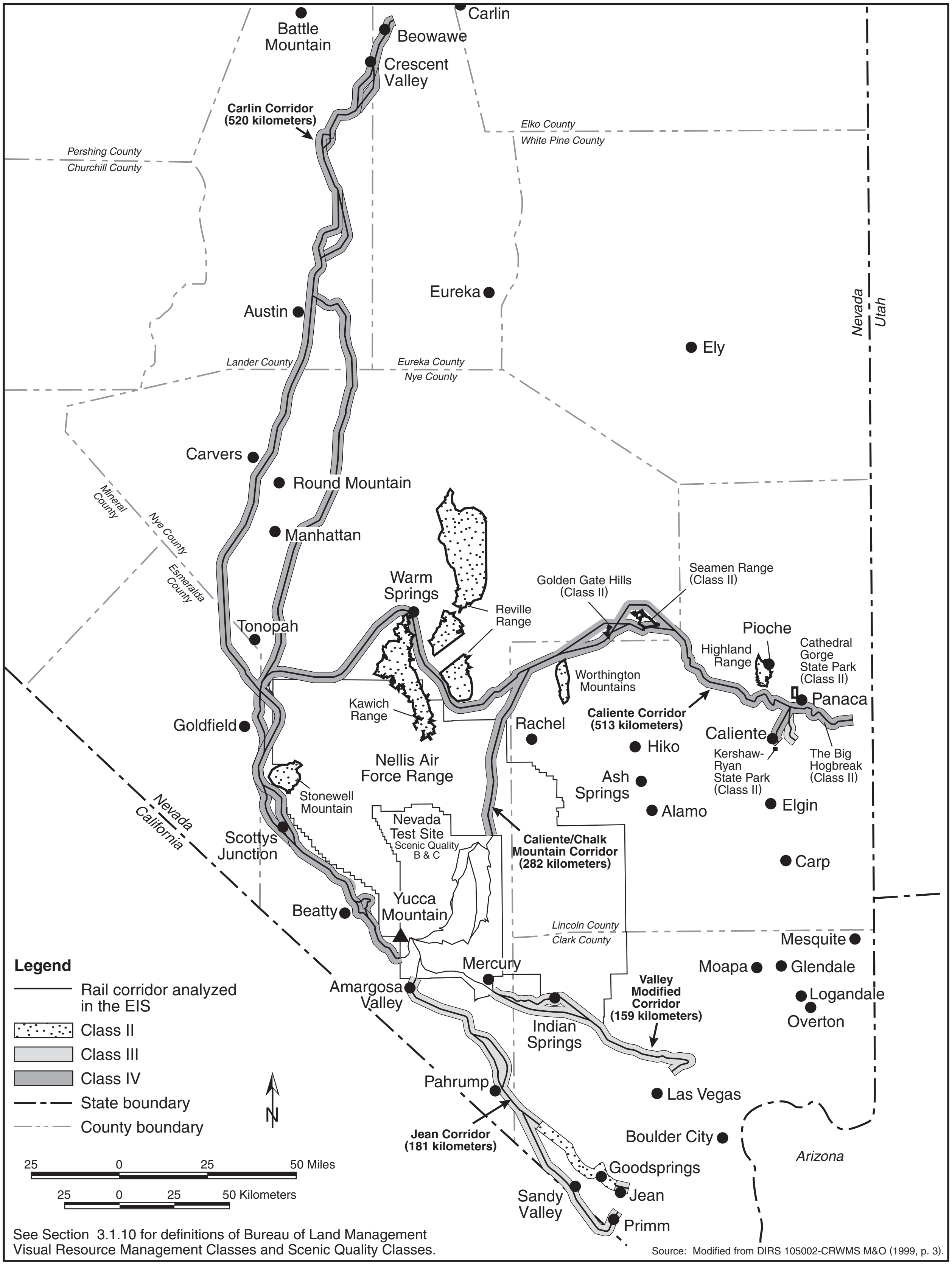

Figure 3-31. Visual Resource Management classes along the potential rail corridors.

3.2.2.1.9 *Utilities, Energy, and Materials*

All five primary rail corridors pass through typically remote Nevada countryside but are within the southern Nevada supply chain for the commodities required during construction and operation. Electric power, which would be available to a limited extent at nearby communities or other locations near power lines, probably would not be needed.

3.2.2.1.10 *Environmental Justice*

The five candidate rail corridors would not appreciably affect counties other than those through which they pass. Section 3.1.13 contains information on the minority and low-income communities in the three counties most involved in the corridors (Clark, Lincoln, and Nye) and includes Figures 3-27 and 3-28, which show locations of minority and low-income communities, respectively, in Nevada. Figures 3-29 and 3-30 provide similar information, at a higher resolution, for the Las Vegas metropolitan area in Clark County. The Carlin corridor is the only route that passes through other counties (Esmeralda, Eureka, and Lander, in addition to Nye). This section contains baseline information on minority and low-income communities in Esmeralda, Eureka, and Lander Counties, in addition to the information shown in Figures 3-27 and 3-28. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (DIRS 105004-CRWMS M&O 1999, all) is the basis for the information in this section. DOE has updated and refined information germane to the environmental justice analysis since the Publication of the Draft EIS, including an additional and more detailed mapping of minority populations (see Appendix J, Section J.3.1.2). Although 2000 Census data concerning minority communities in Nevada were available at the Census block level in time for the Final EIS analysis, 2000 Census data on low-income communities were not. Therefore, the information on low-income communities is from the most current available source, the 1990 Census.

In 2000, the minority population (White Hispanic, Black, Asian/Pacific Islander, American Indian/ Eskimo/Aleut, and Other) of Esmeralda County was about 190, or 20 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 6 of Table DP-1; Esmeralda County). In 1990, there were about 210 persons living in poverty, or 15 percent of the population. No block group in Esmeralda County exceeded the threshold for identification as a low-income community (DIRS 103134-Bureau of the Census 1992, Table P117). (Section 3.1.13 defines minority and low-income communities.)

In 2000, the minority population of Eureka County was about 250 persons, or 15 percent (DIRS 156909-Bureau of the Census 2001, p. 7 of Table DP-1; Eureka County). In 1990, there were about 160 persons living in poverty, or 10 percent of the population. No block group in Eureka County exceeded the threshold for identification as a low-income community (DIRS 103141-Bureau of the Census 1992, Table P117).

In 2000, the minority population of Lander County was about 1,400 persons, or 24 percent (DIRS 156909-Bureau of the Census 2001, p. 9 of Table DP-1; Lander County). In 1990, there were about 670 persons living in poverty, or 11 percent of the population. No block group in Lander County exceeded the threshold for identification as a low-income community (DIRS 103144-Bureau of the Census 1992, Table P117).

Some detail on the affected environment for environmental justice that was presented in the Draft EIS for rail corridors has been deleted because of a change in the nature and level of available information. Because of the differences in the level of data between the minority and low-income categories, a combined, parallel discussion is no longer appropriate. The baseline presentation of information now relies on the Section 3.1.13 figures referenced above to identify locations of minority and low-income communities in proximity to the candidate rail corridors.

3.2.2.2 Heavy-Haul Truck Route and Intermodal Transfer Station Environmental Baseline

This section discusses the environmental characteristics of counties and land areas that could be affected by the construction and operation of an intermodal transfer station and the operation of heavy-haul trucks carrying spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository on Nevada highways. The discussion describes existing environmental conditions in the candidate areas where an intermodal transfer station could be located along Nevada highway routes that could be used for the heavy-haul truck transportation of casks containing spent nuclear fuel and high-level radioactive waste. The candidate locations for an intermodal transfer station are near the communities of Caliente, Sloan, and Jean, and northeast of Las Vegas near Dry Lake on the Union Pacific Railroad Valley siding. These locations can be grouped into three general sites near existing rail lines and highways: near Caliente (Caliente), southeast of Las Vegas (Sloan/Jean), and northeast of Las Vegas (Apex/Dry Lake). DOE is considering more than one site for the station in each general area.

The heavy-haul trucks would use existing highways that would be upgraded as necessary to accommodate such vehicles. There are five potential heavy-haul truck routes. Three of these routes (Caliente, Caliente/Chalk Mountain, and Caliente/Las Vegas) are associated with the Caliente intermodal transfer station site. The Sloan/Jean and Apex/Dry Lake intermodal transfer station sites are associated with one candidate route each.

To define the existing (or baseline) environment associated with the three candidate intermodal transfer station locations and along the five candidate heavy-haul truck routes, DOE has compiled environmental information for each of the following subject areas.

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.2.1)
- *Air quality and climate:* The quality of the air and climate (Section 3.2.2.2.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.2.3)
- *Biological resources:* Important biological resources (Section 3.2.2.2.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.2.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.2.6)
- *Noise and vibration:* The existing noise environments (Section 3.2.2.2.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.2.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.2.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.2.10)
- *Existing traffic on potential routes for heavy-haul trucks:* Existing traffic in terms of level of service (on the five alternative heavy-haul truck routes) (Section 3.2.2.2.11)

A Geographic Information System provided population distributions for the different population zones (urban, rural, and suburban) along the alternative highway routes for heavy-haul trucks. This approach, which Chapter 6 and Appendix J describe in detail, differs from the national transportation analysis discussed in Section 3.2.1 and which used the HIGHWAY computer program (DIRS 104780-Johnson et al. 1993, all). DOE expects the waste quantities generated by intermodal transfer station construction to be small in comparison to those from repository construction and operation. Therefore, this discussion does not include existing waste disposal infrastructure along the routes.

DOE evaluated potential impacts of the implementing alternatives in the region of influence for each of the following subject areas. Table 3-54 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict potentially large impacts related to heavy-haul infrastructure construction and operations.

Table 3-54. Regions of influence for heavy-haul implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or for which ownership or use would change as a result of construction and use of an intermodal transfer station and associated highway route
Air quality and climate	The atmosphere in the vicinity of sources of criteria pollutants that would be emitted during construction and operations, and particularly the Las Vegas Valley for implementing alternatives in which the construction and operation of an intermodal transfer station and associated heavy-haul truck route could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards.
Hydrology	*Surface water:* areas where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that would be affected by eroded soil or potential spills of construction contaminants
	Groundwater: aquifers that would underlie areas of construction and operations and that could be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands, that could be disturbed by construction and operation of an intermodal transfer station and associated heavy-haul truck route; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flow
Cultural resources	Land areas that would be disturbed by the construction and operation of an intermodal transfer station and associated heavy-haul truck route
Socioeconomic environments	Clark, Lincoln, Nye, and other counties that a route for heavy-haul vehicles could traverse
Occupational and public health and safety	800 meters[a] on each side of the route for heavy-haul vehicles for incident-free transportation, 80-kilometer[b] radius for potential impacts from accidents
Noise and vibration	Inhabited commercial and residential areas where noise or vibration from the construction and operation of an intermodal transfer station and associated routes for heavy-haul vehicles could be a concern
Aesthetics	The landscapes along potential routes for heavy-haul vehicles and at potential locations for intermodal transfer station where aesthetic quality could be affected by construction and operation
Utilities energy, and materials	Local, regional, and national supply infrastructure that would be required to support construction and operation of an intermodal transfer station and associated route for heavy-haul vehicles
Environmental justice	Locations of minority, low-income, and Native American populations along the heavy-haul truck implementing alternatives; includes the regions of influence for each of the individual subject or impact areas.

a. 800 meters = 0.5 mile.
b. 80 kilometers = 50 miles.

3.2.2.2.1 *Land Use and Ownership*

This section describes existing land use and ownership for the candidate intermodal transfer station locations and for the candidate heavy-haul truck routes. Table 3-55 summarizes the size and ownership of the land parcels DOE considered for each site at the three candidate locations. An intermodal transfer station and support area would require about 0.2 square kilometer (50 acres), so in some cases the ultimate commitment of land would be much less than the parcel size under consideration.

Caliente. DOE has identified two potential locations for an intermodal transfer station southwest of the City of Caliente. Table 3-55 lists the ownership of the land involved. Both sites would use a local road to provide access to U.S. 93, the starting point for all three of the heavy-haul truck routes associated with this intermodal transfer station. Both parcels being considered are in the Rainbow Canyon section of Meadow Valley Wash. This canyon is used for ranching and a variety of recreational purposes and is the route of the Union Pacific railroad. Kershaw-Ryan State Park is across Meadow Valley Wash about 0.4 kilometer (0.25 mile) east of the station sites (DIRS 104873-CRWMS M&O 1997, all). Based on visual observations of the locations, the parcels are currently used as a wastewater treatment facility operated by the City of Caliente. Land near the facility is used for hay production.

Table 3-55. Land areas under consideration for candidate intermodal transfer station sites (square kilometers).[a,b]

Potential location	Total area	Commitment: Percentage current ownership or control[c] — BLM	City of Caliente[d]
Caliente			
North Site	0.5		100
South Site	0.25		100
Sloan/Jean			
North Site	3.3	100	
Middle Site	3.1	100	
South Site	1	100	
Apex/Dry Lake			
Northwest Site	3.5	100	
Northeast Site	0.18	100	
South Site	0.96	100	

a. Sources: DIRS 104873-CRWMS M&O (1997, all); DIRS 155985-CRWMS M&O (1997, all); DIRS 155984-CRWMS M&O (1997, all); DIRS 155986-CRWMS M&O (1997, all).
b. To convert square kilometers to acres, multiply by 247.1.
c. Bureau of Land Management property is public land administered by the Bureau.
d. "City of Caliente" designates patented land owned by the city. A small undesignated portion of both Caliente sites is Bureau of Land Management land.

Sloan/Jean. DOE has identified three possible parcels in the area of Sloan and Jean for potential use as the location of an intermodal transfer station. Each provides adequate land area adjacent to the Union Pacific mainline and has access to nearby existing roadways. Figure 6-21 in Chapter 6 shows these sites. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. The parcels are currently used for recreation and mining. Detailed information on land use is available in the *Proposed Las Vegas Resource Management Plan and Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

Apex/Dry Lake. DOE has identified three land parcels near the intersection of U.S. 93 and Interstate 15 at the Apex and Dry Lake areas northeast of Las Vegas for the possible location of an intermodal transfer station. Each parcel provides adequate land area close to the Union Pacific mainline and has access to existing roadways. The parcels are crossed by several roads and appear to be used mostly for recreation. The Bureau of Land Management controls all lands associated with these parcels through its Las Vegas Field Office. Detailed information on land use is available in DIRS 103079-BLM (1998, all). The Moapa Indian Reservation is about 5 kilometers (3 miles) north of the proposed station site. The Dry Lake solar enterprise zone is almost 5 kilometers west of the site (DIRS 101811-DOE 1996, p. 4-227). The Apex industrial complex is about 16 kilometers (10 miles) to the southwest. Tenants at the complex include Kerr-McGee Chemical Corporation, Chemstar Inc., and Georgia Pacific Corporation. Silver State Disposal operates a waste landfill and waste-processing facilities east of I-15 about 5 kilometers south of the southernmost site. The Apex area is also proposed for the construction of several new power-generating plants.

Routes for Heavy-Haul Trucks. The five possible routes that heavy-haul trucks could use in Nevada—Caliente, Caliente/Las Vegas, Caliente/Chalk Mountain, Sloan/Jean, and Apex/Dry Lake—have existing highways in established rights-of-way. The routes use combinations of highways that, after improvement, heavy-haul trucks could use to travel from an intermodal transfer station at a mainline railroad to the repository.

3.2.2.2.2 *Air Quality and Climate*

This section summarizes existing air quality and climate conditions for each of the candidate intermodal transfer station sites and the five candidate heavy-haul truck routes.

Air Quality. Both the Caliente and Apex/Dry Lake sites are in areas that are either unclassified or in attainment for criteria pollutants (DIRS 104879-Fosmire 1999, all). The northern portion of the Sloan/Jean site is in the Las Vegas nonattainment area (DIRS 104879-Fosmire 1999, all; DIRS 148123-EPA 1999, all; DIRS 149905-EPA 1999, all; DIRS 149906-EPA 1999, all; DIRS 149907-EPA 1999, all). There are no State of Nevada air quality monitoring stations at or near either the Caliente or Apex/Dry Lake site (DIRS 103404-Bureau of Air Quality 1999, pp. A1-1 through A1-9). Clark County operates a particulate matter (PM_{10}) monitoring station at Jean.

The Caliente and Caliente/Chalk Mountain heavy-haul truck routes both pass through rural parts of Nevada. These areas are either unclassifiable or in attainment for criteria pollutants. The air quality in these areas is good. There are no State of Nevada air quality monitoring stations along these routes (DIRS 103404-Bureau of Air Quality 1999, pp. A1-1 through A1-9). These statements are also true for the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake routes before they enter and after they leave the Las Vegas Valley.

The air quality in the segments of the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake routes that pass through the Las Vegas Valley and extend part of the way to Indian Springs is in serious nonattainment for particulate matter (PM_{10}) (DIRS 149905-EPA 1999, Region 9 PM_{10} Nonattainment Areas). Clark County adopted a revised implementation plan in 2001 for demonstrating PM_{10} attainment (DIRS 155557-Clark County 2001, Executive Summary) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration of the 24-hour standard from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. A decision has not yet been made on the County's request for an extension to the attainment period. The Environmental Protection Agency has acknowledged the request, but has not yet completed their formal review of the revised implementation plan (DIRS 156896-Davis 2001, all).

In addition, the Las Vegas Valley air basin is in nonattainment for the 3-hour carbon monoxide standard, largely the result of vehicular emissions. Clark County adopted a State Implementation Plan for carbon monoxide to achieve the attainment criteria by December 2000 (DIRS 156706-Clark County 2000, all). The Plan outlines a methodology to maintain acceptable carbon monoxide concentrations through transportation planning and control measures. The Environmental Protection Agency has deemed the motor vehicle carbon monoxide estimates indicated in the Plan *adequate* (65 *FR* 71313; November 30, 2000). In 2000, monitoring results indicated that the Plan criteria had been met (DIRS 157158-EPA 2000, all); however, the area is still officially classified as in nonattainment.

Climate. This section describes the climate affecting the candidate intermodal transfer station sites and heavy-haul truck routes.

The community of Caliente and the site of the proposed intermodal transfer station are in Meadow Valley Wash, a relatively narrow canyon that trends to the northeast. Small canyons enter Meadow Valley Wash from the east and west. The diurnal cycle of up-canyon winds during the daytime and down-canyon winds at night minimizes periods of calm conditions. The community of Caliente is about 1,300 meters (4,300 feet) above sea level. Average annual precipitation is about 22 centimeters (9.0 inches); average snowfall is about 35 centimeters (14 inches) (DIRS 100117-CRWMS M&O 1997, p. A-14). The maximum single-day precipitation record is 5.4 centimeters (2.1 inches). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime. The mean maximum July temperature is 35ºC (95ºF), and the mean minimum January temperature is -8.2ºC (18ºF) (DIRS 100117-CRWMS M&O 1997, p. A-14).

The climate at the Sloan/Jean and Apex/Dry Lake station sites is similar to Las Vegas (DIRS 100117-CRWMS M&O 1997, Section 4.1; DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). Precipitation in Las Vegas averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare. Occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime. The maximum recorded daily precipitation is 6.6 centimeters (2.6 inches). The mean maximum July temperature is 40ºC (104ºF), and the mean minimum January temperature is 0.9ºC (33ºF).

The Caliente and Caliente/Chalk Mountain heavy-haul truck routes, and to a lesser extent the Caliente/Las Vegas route, cross mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nevada the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches) in central White Pine and Nye Counties; annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). The southern portion of the Caliente/Las Vegas route, through Clark County, is at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). Along all three of these routes, occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summertime.

The Sloan/Jean and Apex/Dry Lake heavy-haul truck routes are at low elevations where precipitation averages between 10 and 20 centimeters (4 and 8 inches) a year and snowfall is rare (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). However, occasional brief periods of intense rainfall, at rates exceeding 5 centimeters (2 inches) an hour, can occur in the summertime.

3.2.2.2.3 *Hydrology*

This section describes hydrologic conditions in terms of surface water and groundwater near the candidate intermodal transfer stations and along the candidate heavy-haul shipment routes.

3.2.2.2.3.1 Surface Water. DOE studied each of the candidate intermodal transfer station sites and associated highway routes for their proximity to sensitive environmental resources (DIRS 104593-CRWMS M&O 1999, Appendixes J, K, L, M, N, and O), including surface waters and riparian lands. Table 3-56 summarizes potential surface-water-related resources within a 1-kilometer (0.6-mile) region of influence from the station sites and highway routes that heavy-haul trucks would use. The table lists surface-water-related resources associated with the Caliente intermodal transfer station site and with each of the potential routes starting at that site. No surface-water-related resources were identified in the region of influence for either the Sloan/Jean or Apex/Dry Lake station site, and none were identified along the associated routes.

Table 3-56. Surface-water-related resources at potential intermodal transfer station sites and along candidate routes for heavy-haul trucks.[a]

Station or route	Distance from station or route (kilometers)[b]	Feature
Caliente station	0.5	Spring – unnamed spring, southwest of Caliente and northwest of station site
	0.2	Riparian/stream – perennial stream and riparian habitat along Meadow Valley Wash
Caliente route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.5	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to Rachel	0.01 - 0.07	Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road
Rachel to Yucca Mountain (via Tonopah)	0.03 - 0.02	Riparian area – Twin Spring Slough and Echo Canyon Reservoir, along State Highway 375, east of Warm Springs
	0.2	Springs – Twin Springs, 15 kilometers east of Warm Springs
	Within - 0.2	Springs – Warm Springs, group of thermal springs near town of Warm Springs, outflow crosses the route
	0.4	Spring – Fivemile Spring in Stone Cabin Valley
	1.0	Spring – Rabbit Spring, west of Goldfield
	0.1	Spring – unnamed, in upper Oasis Valley, northwest of Beatty
	0.3	Spring – unnamed, in upper Oasis Valley
	0.4	Spring – unnamed, in upper Oasis Valley, northwest of Beatty
	0.4	Spring – unnamed, east of U.S. 95 in upper Oasis Valley
	0.4	Spring – Fleur-de-lis Spring at Springdale
	0.1	Spring – unnamed, east of U.S. 95 in upper Oasis Valley
	0.1	Spring – unnamed, east of U.S. 95 north of Beatty
	0.9	Spring – unnamed, east of U.S. 95, north of Beatty
	0.9	Spring – Gross Spring, east of U.S. 95, north of Beatty
	Within	River – Amargosa River, parallels U.S. 95 for about 23 kilometers near Beatty
	0.2 - 0.3	Springs – group of thermal springs on east border of U.S. 95, north of Beatty
	0.3	Spring – Well Spring, west of U.S. 95, north of Beatty
	0.4	Spring – Ute Spring, north of Beatty
	0.6	Spring – unnamed, west of U.S. 95, north of Beatty
	0.3	Spring – Revert Spring in Beatty
	0.3	Spring – unnamed, east of U.S. 95, south of Beatty
Caliente/Chalk Mountain Route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.5	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to Rachel	0.01 - 0.07	Spring – Crystal Springs, group of thermal springs near Town of Crystal Springs, flows along road
Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site)	0.9	Spring – Cane Spring, north of Skull Mountain on Nevada Test Site
Caliente/Las Vegas route		
Caliente to Crystal Springs	0.3	Spring – unnamed, west of Caliente
	0.5	Spring – unnamed, in Newman Canyon
	0.8	Spring – unnamed, in Newman Canyon
Crystal Springs to I-15 (via U.S. 93)	0.7	Spring – Pedretti Seeps, 3.5 kilometers southeast of Crystal Springs
	0.7	Spring – unnamed, west of route, just south of Pedretti Seeps
	0.8	Spring – Deacon Spring, 5 kilometers southeast of State Highway 375
	1.0	Spring – Brownie Spring, 5 kilometers southeast of State Highway 375
	Within - 0.5	Spring – Ash Springs (76 meters from road), 7 kilometers southeast of State Highway 375, flows under road to Ash Springs Pool and to Pahranagat Creek and irrigation ditches
	0.7	Spring – Grove Spring, 1.5 kilometers north of Upper Pahranagat Valley
	0.1	Lakes – route parallels Upper and Lower Pahranagat lakes and associated inundated areas (marshes) for about 15 kilometers
	0.1	Spring – unnamed, 0.2 kilometers west of U.S. 93 and Maynard Lake
	0.1	Lake – Maynard Lake, route borders for about 1 kilometer
	0.8	Spring – Coyote Springs, 21.5 kilometers north of junction with State Route 168
U.S. 93/I-15 junction to U.S. 95 (via the proposed northern beltway)		None
U.S. 95 to Yucca Mountain		None
Sloan/Jean station		None identified
Sloan/Jean route		None identified
Apex/Dry Lake station		None identified
Apex/Dry Lake route		None identified

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes J, K, L, M, N, and O).
b. To convert kilometers to miles, multiply by 0.62137.

Appendix L of this EIS is a floodplain/wetland assessment for the proposed repository action, including the Nevada transportation routes. With respect to heavy-haul truck routes, the appendix addressed floodplain actions that could be required near the repository site as well as at the intermodal transfer station locations. With respect to the heavy-haul truck routes, the Proposed Action would involve modifications of existing roadways, which should already incorporate appropriate flood design, so no new floodplain issues are expected.

Intermodal Transfer Station Locations

Caliente. Flood Insurance Rate Maps published by the Federal Emergency Management Agency address the area in Meadow Valley Wash south of Caliente where the two proposed sites for the Caliente intermodal transfer stations are located. The maps (DIRS 148130-FEMA 1988, all; DIRS 148131-FEMA 1988, all) show two areas on the west side of the Union Pacific rail tracks that match up with the proposed sites. Both areas are outside the inundation boundary of the 100-year flood, but within the boundary of the 500-year flood.

Sloan/Jean. Based on Flood Insurance Rate Maps, the southernmost site proposed for the Jean intermodal transfer station (on the west site of the Union Pacific rail tracks) would be in the same general area as a 100-year flood inundation zone. The flood map (DIRS 148132-FEMA 1995, all) shows three separate washes or drainage areas that originate in the area northwest of the intersection of State Route 161 (or State Route 53 on the map) and I-15. From their origins, the washes drain to the southeast, beneath I-15, and join a southwest drainage that parallels the rail tracks until it reaches the Roach Lake area to the south. The southern Jean intermodal transfer station site is in the area where the first southeast-draining channel curves around into a southwest-draining channel. The 100-year flood inundation areas appear to be about 150 meters (500 feet) wide for these drainage channels.

The northern site proposed for the Jean intermodal transfer station is on the east side of the tracks in an area where the map shows no inundation lines (DIRS 148132-FEMA 1995, all). In fact, the map identifies this area with a Zone X designation, indicating it is outside the 500-year floodplain.

According to the Federal Emergency Management Agency Map Index for Clark County, Nevada, and Incorporated Areas (DIRS 148133-FEMA 1995, all), the northernmost site for this area, the Sloan intermodal transfer station site, is in an area (Panel 32003C2925 D) with no printed map. The Map Index further describes these unprinted areas as Zone X, indicating they are outside the 500-year floodplain.

Apex/Dry Lake. Based on the Flood Insurance Rate Map for the area of the Apex/Dry Lake intermodal transfer station sites (DIRS 148134-FEMA 1995, all), the three proposed locations are outside any 100-year flood zone. The nearest flood zone identified on the map is for the Dry Lake area west of the sites. At its closest, the inundation area approaches to within about 300 meters (1,000 feet) of I-15, but the intermodal transfer station site would be on the other side (east side) of I-15. The northern site would appear to be at least 300 meters from the inundation zone. All three areas are in Zone X (determined to be outside the 500-year floodplain).

Highway Routes for Heavy-Haul Trucks

Potential hydrologic hazards along a heavy-haul truck route include flash flooding and debris flow. All routes have potential flash flooding concerns. However, because of the required road upgrades, the robustness of the vehicle and shipping cask, and the en route safeguards (for example, escorts), flash flooding or standing water is not expected to be a serious threat to heavy-haul shipments.

3.2.2.2.3.2 Groundwater. As discussed in relation to the potential rail corridors, all of Nevada has been divided into groundwater basins and sub-basins, with these latter, smaller divisions termed hydrographic areas. The water resource planning and management information generated by the State of Nevada for these hydrographic areas provides the basis for groundwater information presented for both intermodal transfer station locations and the candidate highway routes that would be used by heavy-haul trucks. The following paragraphs provide an overview of the groundwater conditions at these sites and along the associated routes. Water demand at an intermodal transfer station would be small for both construction and operations. Water needs during operations would consist primarily of the needs of the personnel that staff the station. Water needs for construction and operations would be met by trucking water to the site, installing a well, or possibly by connection to a local water distribution system. This demand would be unlikely to cause noticeable change in water consumption rates for the area. Consequently, no baseline water-use information is provided.

Intermodal Transfer Station Locations

Caliente. The two sites southwest of Caliente being considered for the intermodal transfer station are close to one another and are located in Nevada's Colorado River Basin (designated Hydrographic Region 13). This hydrographic region covers about 32,000 square kilometers (12,000 square miles) and parts of four counties (DIRS 148165-NDWP 1999, Region 13). The Colorado River Basin is further divided into 27 hydrographic areas including Lower Meadow Valley Wash (Area 205), where the Caliente sites are located. This area has been assigned a "Designated Groundwater Basin" status, which means that its permitted water rights approach or exceed the estimated perennial yield and its water resources are being depleted or require additional administration. The additional administration normally includes a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.) for the groundwater from this area.

Sloan/Jean. The Jean sites being considered for the intermodal transfer station are in Nevada's Central Hydrographic Region (also designated Region No. 10). This is the largest hydrographic region in Nevada, encompassing about 120,000 square kilometers (46,000 square miles) and parts of 13 counties (DIRS 148165-NDWP 1999, Region 10). The Central Region has 90 hydrographic areas and sub-areas, including Ivanpah Valley/Northern Part (Area 164A), where the Jean sites are located. This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater in the vicinity of the candidate Jean sites is approximately 150 meters (490 feet) (DIRS 101933-Thomas, Welch, and Dettinger 1996, Plate 1).

The site near Sloan being considered for the intermodal transfer station is in Nevada's Colorado River Basin (Hydrographic Region 13), as described for the Caliente sites. The Sloan site is in the hydrographic area designated Las Vegas Valley (Area 212). This area has also been assigned a Designated Groundwater Basin status. The depth to groundwater at Sloan is approximately 240 meters (790 feet) (DIRS 101933-Thomas, Welch, and Dettinger 1996, Plate 1).

Apex/Dry Lake. The three sites near Apex/Dry Lake being considered for the intermodal transfer station are close to one another and are in Nevada's Colorado River Basin, as described for the Caliente sites. The Apex/Dry Lake sites are in the hydrographic area designated Garnet Valley (Area 216). The estimated perennial yield for the groundwater in this area is only 490,000 cubic meters (400 acre-feet), but it is not a Designated Groundwater Basin. The depth to groundwater at Apex/Dry Lake is about 60 meters (200 feet) (DIRS 101933-Thomas, Welch, and Dettinger 1996, Plate 1).

Highway Routes for Heavy-Haul Trucks

The highway routes in Nevada that heavy-haul trucks could use cross through several hydrographic regions and a greater number of hydrographic areas. To identify groundwater that could potentially be affected, a map of these hydrographic areas (DIRS 101486-Bauer et al. 1996, p. 543) was overlain with a drawing of the proposed highway routes to get a reasonable approximation of the areas that would be crossed. The results of this effort are listed in Table 3-57. This table also lists estimates of the perennial yield for each of the hydrographic areas crossed and if the area is a Designated Groundwater Basin. Basins with this designation are the areas where additional water demand would be most likely to adversely affect local groundwater resources. None of the candidate routes would totally avoid

Table 3-57. Hydrographic areas (groundwater basins) crossed by candidate routes for heavy-haul trucks.[a]

Route	Hydrographic area Number	Hydrographic area Name	Perennial yield[b,c] (acre-feet)[d]	Designated groundwater basin[e,f]
Caliente				
Caliente to Crystal Springs (near Hiko)	203	Panaca Valley	9,000	Yes
	181	Dry Lake Valley	2,500	No
	182	Delamar Valley	3,000	No
Crystal Springs to Rachel	209	Pahranagat Valley	25,000	No
	169A	Tikaboo Valley, Northern Part	1,300	No
Rachel to Yucca Mountain (via Tonopah)	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes
	173A	Railroad Valley, Southern Part	2,800	No
	173B	Railroad Valley, Northern Part	75,000	No
	156	Hot Creek	5,500	No
	149	Stone Cabin Valley	2,000	Yes
	141	Ralston Valley	6,000	Yes
	137A	Tonopah Flat	6,000	Yes
	142	Alkali Spring Valley	3,000	No
	144	Lida Valley	350	No
	146	Sarcobatus Flat	3,000	Yes
	228	Oasis Valley	1,000	Yes
	230	Amargosa Valley	24,000	Yes
	229	Crater Flat	220	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Caliente/Chalk Mountain				
Caliente to Crystal Springs (near Hiko)	203 to 209	See Caliente Route		
Crystal Springs to Rachel	209 to 170	See Caliente Route		
Rachel to Yucca Mountain (via Nellis Air Force Range and Nevada Test Site)	170			
	158A	Emigrant Valley and Groom Lake Valley	2,800	No
	159	Yucca Flat	350	No
	160	Frenchman Flat	16,000	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Caliente/Las Vegas				
Caliente to Crystal Springs (near Hiko)	203 to 209	See Caliente Route		
Crystal Springs (near Hiko) to U.S. 93/I-15 junction at Dry Lake	209			
	210	Coyote Springs Valley	18,000	Yes
	217	Hidden Valley	200	No
U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction	216	Garnet Valley	400	No
U.S. 95 junction to Yucca Mountain	212	Las Vegas Valley	25,000	Yes
	211	Three Lakes Valley, Southern Part	5,000	Yes
	161	Indian Springs Valley	500	Yes
	225	Mercury Valley	250	No
	226	Rock Valley	30	No
	227A	Fortymile Canyon and Jackass Flats	880[g]	No
Sloan/Jean[h]				
Jean to U.S. 95 junction	164A	Ivanpah Valley, Northern Part	700	Yes
	165	Jean Lake Valley	50	Yes
U.S. 95 junction to Yucca Mountain	212 to 227A	See Caliente-Las Vegas route		
Apex/Dry Lake				
U.S. 93/I-15 junction at Dry Lake to U.S. 95 junction	216 to 212	See Caliente-Las Vegas route		
U.S. 95 junction to Yucca Mountain	212 to 227A	See Caliente-Las Vegas route		

a. Source: DIRS 101486-Bauer et al. (1996, pp. 542 and 543 with route map overlay).
b. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.
c. Source: DIRS 103406-NDWP (1992, Regions 10, 13, and 14); for Hydrographic Areas 225 through 230 the source is DIRS 147766-Thiel (1999, pp. 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet for the combined area of hydrographic areas 225 through 230 (DIRS 103406-NDWP 1992, Region 14).
d. To convert acre-feet to cubic meters, multiply by 1,233.49.
e. "Yes" indicates that the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield, and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.
f. Source: DIRS 148165-NDWP (1999, Regions 10, 13, and 14).
g. The perennial yield value shown for Area 227A is the lowest estimated value in DIRS 147766-Thiel (1999, p. 8), and is accompanied by the additional qualification: 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 720,000 cubic meters (580 acre-feet) for the western two-thirds.
h. The hydrographic areas listed for the Sloan/Jean Route are based on the intermodal transfer station located at Jean. For the Sloan location, the route would begin with Hydrographic Area 212, then proceed as shown.

Designated Groundwater Basins. However, the Caliente/Chalk Mountain route would cross only two designated basins: one in the Lower Meadow Valley Wash at the beginning of the route and one at Penoyer Valley where the Caliente and Caliente/Chalk Mountain routes split.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-11. For simplicity, the perennial yield values listed in Table 3-57 generally come from a single source (DIRS 103406-NDWP 1992, Regions 10, 13, and 14) and, therefore, are not ranges of values. The hydrographic areas in the vicinity of Yucca Mountain (that is, Areas 225 through 230) are the exception to perennial yield values coming from the single source. The perennial yield values for these areas come from DIRS 147766-Thiel (1999, pp. 6 to 12), which compiles estimates from several sources. The table lists the lowest values presented in that document.

3.2.2.2.4 *Biological Resources*

The existing biological environment described in this section includes the areas inside the boundaries of the intermodal transfer station sites and within 100 meters (about 330 feet) of the centerline of the heavy-haul truck routes. It also includes springs within 400 meters (0.25 mile) of the intermodal transfer sites and the routes. The section discusses environmental settings and important biological resources for each candidate station and associated heavy-haul truck routes. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, all).

Caliente Intermodal Transfer Station

The 0.7-square kilometer (170-acre) area DOE is considering for the Caliente intermodal transfer station is about 1 kilometer (0.6 mile) southwest of Caliente and less than 500 meters (1,600 feet) west of Meadow Valley Wash. This area is at an elevation of about 1,200 meters (3,900 feet). The land cover types at this site are primarily agricultural—pasture, 88 percent, and salt desert scrub, 12 percent.

No species classified as Federally threatened or endangered, as State protected, or as sensitive by the Bureau of Land Management occur in the proposed location of the Caliente intermodal transfer station. Although the Federally endangered Southwestern willow flycatcher has been detected in Meadow Valley Wash, there is no habitat for this species on this site (DIRS 152511-Brocoum 2000, pp. A-9 to A-13). Two fish classified as sensitive by Bureau of Land Management, the Meadow Valley Wash speckled dace (also classified as sensitive by Nevada) and the Meadow Valley Wash desert sucker (*Catostomus clarki* ssp.), occur in the Meadow Valley Wash.

There is no designated game habitat in this area, but the adjacent Meadow Valley Wash is classified as important habitat for Gambel's quail (DIRS 101504-BLM 1979, pp. 2-34 and 2-35).

There are no springs at the proposed station location, but there are springs adjacent to the site and some areas within the site have soils and plant species indicative of wetlands (DIRS 104593-CRWMS M&O 1999, pp. 3-35 and 3-36). Many of these moist areas are probably the result of irrigation with treated effluent from the wastewater treatment facility within the site, but some might qualify as wetlands or other waters of the United States if they are the result of outflow from nearby springs or the adjacent Meadow Valley Wash. The adjacent perennial stream and riparian habitat along Meadow Valley Wash also might be classified as a wetlands or other waters of the United States, although there has been no formal wetlands delineation.

Caliente Route. This route passes through the southern Great Basin Desert from the beginning of the route in Caliente to near Beatty. From south of Beatty to Yucca Mountain, the route passes through the Mojave Desert. The predominant land cover types along the entire route are salt desert scrub (49 percent), sagebrush (14 percent), and creosote-bursage (13 percent).

Three threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente heavy-haul truck route. The Hiko White River springfish (*Crenicthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (DIRS 103262-FWS 1998, p. 16), which is about 75 meters (250 feet) south of State Route 375 at its intersection with State Route 318, west of U.S. 93. The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). A population of the Railroad Valley springfish (*Crenicthys nevadae*, Federal threatened) has been introduced into Warm Springs, the outflow of which crosses U.S. Highway 6 (DIRS 103261-FWS 1996, p. 20). The southern part of the route, along U.S. 95 from Beatty to Yucca Mountain, is within the range of the desert tortoise (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative number of tortoises in this area is low (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411).

Six species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route. The Pahranagat speckled dace (*Rhinichthys osculus velfier*) occurs in Crystal Springs. The Railroad Valley tui chub (*Gila bicolor* ssp 7) (also classified as sensitive by Nevada) occurs in Twin Spring Slough along State Route 375. The Amargosa toad (*Bufo nelsoni*) and the Oasis Valley speckled dace (*Rhinichthys osculus* ssp 1) (both also classified as protected by Nevada) occur in the Amargosa River and elsewhere in the Oasis Valley. Two bats, the Townsend's big-eared bat (*Corynorhinus townsendii*) and fringed myotis (*Myotis thysanodes*), have been documented near the southern end of the route, and other bats classified as sensitive by the Bureau of Land Management might occur near the route. The chuckwalla lizard also might occur in suitable habitat along the southern end of the route.

This route crosses eight areas designated as game habitat (DIRS 101504-BLM 1979, pp. 2-27 to 2-36; DIRS 101523-BLM 1994, Maps 9, 10, 12, and 13). Portions of Meadow Valley Wash are designated important habitat for Gambel's quail and waterfowl. The route crosses mule deer habitat in Newman Canyon, in the Pahroc Range, in the Pahranagat Range, and northwest of the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range, and pronghorn habitat northwest of the Groom Range and from west of Sand Spring Valley through Railroad, Stone Cabin, and Ralston Valleys.

Nineteen springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be considered wetlands or other waters of the United States under Section 404 of the Clean Water Act, although no formal wetlands delineation has been conducted. The route is adjacent to Meadow Valley Wash at the proposed location of the intermodal transfer station. There is an unnamed spring near U.S. 93 west of Caliente. Crystal Spring and its outflow are about 10 meters (33 feet) from State Route 375, which also passes within 250 meters (820 feet) of Twin and Warm Springs and crosses their outflows. Fivemile Spring is about 0.4 kilometer from U.S. 6 in Stone Cabin Valley. U.S. 95 passes within 0.4 kilometer of 12 springs or groups of springs in the Oasis Valley and along the Amargosa River, and crosses the Amargosa River at Beatty. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route also borders the Bureau of Land Management Oasis Valley Area of Critical Environmental Concern, which is designed to protect riparian areas and sensitive species in Oasis Valley south of Springdale (DIRS 104593-CRWMS M&O 1999, p. 3-32).

Caliente/Chalk Mountain Route. From Caliente to Crystal Springs, this heavy-haul truck route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Rachel the route crosses Hancock Summit and Tikaboo Valley at elevations ranging from about 1,300 to 1,700 meters (4,300 to 5,600 feet). From Rachel to Yucca Mountain the route passes through Sand Spring and Emigrant Valleys, and Yucca Flat, Frenchman Flat, and Jackass Flats, at elevations from 1,700 to

1,900 meters (5,600 to 6,200 feet). Along the entire route, the predominant land cover types are salt desert scrub (37 percent), blackbrush (16 percent), sagebrush (11 percent), and creosote-bursage (10 percent).

Two resident threatened or endangered species occur within 100 meters (about 330 feet) of the Caliente/Chalk Mountain heavy-haul truck route. The Hiko White River springfish (*Crenichthys baileyi grandis*, Federally endangered) occurs in Crystal Springs (DIRS 103262-FWS 1998, p. 16). The springs and outflow, which come within about 10 meters (33 feet) of State Route 375, are critical habitat for the Hiko White River springfish (50 CFR 17.95). The part of the route from the northern end of Frenchman Flat to Yucca Mountain is within the range of the desert tortoise (DIRS 101915-Rautenstrauch, Brown, and Goodwin 1994, all). This area is not classified as critical habitat for desert tortoises (50 CFR 17.95), and the relative abundance of tortoises in this area is low (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411).

Three species classified as sensitive by the Bureau of Land Management occur within 100 meters (about 330 feet) of this route. The Pahranagat speckled dace occurs in Crystal Springs, Ripley's springparsley occurs in a number of locations in Yucca Flat on the Nevada Test Site, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of bats classified as sensitive by the Bureau of Land Management might occur along the route and the southern end of the route is within the range of the chuckwalla.

This route crosses six areas designated as game habitat (DIRS 101504-BLM 1979, pp. 2-27 to 2-36; DIRS 101523-BLM 1994, Maps 9, 10, 12, and 13). Meadow Valley Wash is designated important habitat for Gambel's quail and waterfowl. The route crosses mule deer habitat in four areas: west of Caliente, near Pahroc Summit Pass, in the Pahranagat Range, and in the Groom Range. It also crosses bighorn sheep habitat in the Pahranagat Range.

Three springs or riparian areas within 0.4 kilometer (0.25 mile) of the route might be wetlands or other waters of the United States under Section 404 of the Clean Water Act, including Meadow Valley Wash, an unnamed spring near U.S. 93 west of Caliente, and Crystal Springs and its outflow. No formal wetlands delineation has been conducted along this route. This route also crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

Caliente/Las Vegas Route. From Caliente to Crystal Springs, this candidate route crosses the Burnt Spring Range, Dry Lake Valley, Sixmile Flat, and the north end of the South Pahroc Range at elevations from 1,200 to 1,900 meters (3,900 to 6,200 feet). From Crystal Springs to Las Vegas, the route parallels the White River through Pahranagat Valley, and then through Coyote Springs, Hidden, Dry Lake, Las Vegas, Mercury, and Rock Valleys, and crosses Jackass Flats to Yucca Mountain. Elevations along the section from Crystal Springs to Yucca Mountain range from 610 to 1,200 meters (2,000 to 3,900 feet). Along the route the predominant land cover types are creosote-bursage (62 percent) and Mojave mixed scrub (16 percent).

Four resident threatened or endangered species might occur within 100 meters (about 330 feet) of the Caliente/Las Vegas heavy-haul truck route. The section of the route from about Alamo to Yucca Mountain is within the range of the threatened desert tortoise (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). An approximately 100-kilometer (60-mile) section of U.S. 93 from Maynard Lake south to a point approximately 6 kilometers (4 miles) north of I-15 is critical habitat for the desert tortoise (50 CFR 17.95). The relative abundance of desert tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). The White River springfish (*Crenichthys baileyi baileyi*, Federally endangered and Nevada protected) has been found in Ash Springs, less than 100 meters from U.S. 93 in northern Pahranagat Valley (DIRS 103262-FWS 1998, pp. 12 to 14). The route crosses the outflow of Ash Springs, which is designated critical habitat for the White River springfish (50 CFR 17.95). The Pahranagat roundtail chub (*Gila robusta jordani*, Federally endangered and Nevada protected) occurs in Ash Springs, the outflow, and throughout Pahranagat Creek, but now is restricted to an approximately 3.5-kilometer (2.2-mile) length of Pahranagat Creek and approximately 2.5 kilometers (1.6 mile) of irrigation ditch in the area (DIRS 103262-FWS 1998, pp. 11 to 12). Southwestern willow flycatchers might occur in dense riparian vegetation near U.S. 93 in Pahranagat Valley.

Nine other species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of the route. The Pahranagat speckled dace occurs in Ash Springs. The Pahranagat pebblesnail (*Fluminicola merriami*), Pahranagat naucorid (*Pelocoris shoshone shoshone*), and the grated tryonia (*Tryonia clathrata*) occur in Ash Springs, and the Pahranagat Valley montane vole (*Microtus montanus fucosus*) has been observed near the route in Pahranagat National Wildlife Refuge. In addition, pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs along U.S. 93 north of I-15, Ripley's springparsley and Parish's scorpionweed (*Phacelia parishii*) occur adjacent to Jackass Flats Road in eastern Rock Valley, and the fringed myotis has been observed in Fortymile Wash on the Nevada Test Site. A number of other bats classified as sensitive by the Bureau of Land Management occur along the route and most of the route south from Pahranagat Valley is within the range of the chuckwalla and gila monster (*Heloderma suspectus*).

Seven springs, streams, or lakes less than 0.4 kilometer (0.25 mile) from the route might be classified as wetlands under Section 404 of the Clean Water Act, including Meadow Valley Wash, Ash Springs and its outflow, unnamed springs on U.S. 93 west of Caliente and near Maynard Lake, Upper and Lower Pahranagat lakes and their associated marshes, and Maynard Lake. This route also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act.

The route crosses eight areas designated as game habitat (DIRS 101504-BLM 1979, pp. 2-26 to 2-35; DIRS 103079-BLM 1998, Maps 3-7 to 3-9). Meadow Valley Wash and much of Pahranagat Valley are designated as habitat for Gambel's quail and waterfowl, and areas along U.S. 93 north of I-15 are designated as quail habitat. U.S. 93 crosses mule deer habitat west of Caliente and around Maynard Lake, two bighorn sheep migration routes, and crucial bighorn sheep habitat north of the U.S. 93 and I-15 junction.

Sloan/Jean Station and Route

The area that DOE is considering for the Sloan/Jean intermodal transfer station is in Ivanpah Valley. DOE is considering three sites in this valley: southwest of Sloan [3.3 square kilometers (810 acres)], northeast of Jean [3.1 square kilometers (760 acres)], and east of Jean [1 square kilometer (260 acres)]. These sites are at an elevation of about 910 meters (3,000 feet) and have vegetation typical of the Mojave Desert. The predominant land cover type is creosote-bursage (97 percent). Elevations along the associated Sloan/Jean heavy-haul truck route range from about 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along the route include creosote-bursage (78 percent), Mojave mixed scrub (12 percent), and urban development (9 percent).

The three sites that DOE is considering for the Sloan/Jean intermodal transfer station are in the range of the threatened desert tortoise. The abundance of tortoises generally is moderate to high in Ivanpah Valley in relation to other areas in Nevada (DIRS 101840-Karl 1980, pp. 75 to 87; DIRS 101521-BLM 1992, Map 3-13). This area is not critical habitat for desert tortoises (50 CFR 17.95).

One species classified by the Bureau of Land Management as sensitive, and by the State of Nevada as protected, occurs in the candidate Sloan/Jean station sites. The pinto beardtongue (*Penstemon bicolor* ssp. *roseus)* has been observed on the site southwest of Sloan and on the site east of Jean. The only game habitat near these areas is bighorn sheep winter range immediately west of the Sloan site (DIRS 103079-BLM 1998, Maps 2-1, 3-7, 3-8, and 3-9). There are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of these sites (DIRS 104593-CRWMS M&O 1999, p. 3-36).

The only resident threatened or endangered species along the Sloan/Jean heavy-haul truck route is the desert tortoise. The entire route is within the range of the desert tortoise (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). The abundance of tortoises along the first part of the route in Ivanpah Valley is moderate to high in relation to other areas in Nevada (DIRS 101521-BLM 1992, Map 3-13). The abundance of tortoises along the remainder of the route through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low to very low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Four species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route. The pinto beardtongue (*Penstemon bicolor bicolor* and *P. b. roseus*) occurs in the Las Vegas Valley. Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road in eastern Rock Valley on the Nevada Test Site, and the fringed myotis has been observed near the Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitats (DIRS 103079-BLM 1998, Maps 3-7 to 3-9) and there are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile).

Apex/Dry Lake Station and Route

The area that DOE is considering for the Apex/Dry Lake intermodal transfer station is northeast of Las Vegas in Dry Lake Valley. The Department is considering three sites in this area, two to the west of I-15 [0.18 and 3.5 square kilometers (45 and 880 acres)] and one east of the Interstate [0.96 square kilometer (240 acres)] . The elevation of these sites is about 610 meters (2,000 feet). This area is in the Mojave Desert and the predominant land cover type is creosote-bursage (100 percent). The associated route starts at the station area and crosses Las Vegas, Mercury, and Rock Valleys and Jackass Flats to Yucca Mountain at elevations ranging from 700 to 1,100 meters (2,300 to 3,600 feet). Predominant land cover types along this route are creosote-bursage (77 percent) and Mojave mixed scrub (16 percent).

The only resident threatened or endangered species along the Apex/Dry lake heavy-haul truck route is the desert tortoise. The entire route passes through desert tortoise habitat (DIRS 103160-Bury and Germano 1994, pp. 57 to 72), and the relative abundance of tortoises along this route through the Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site generally is low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). This route does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

Three species classified as sensitive by the Bureau of Land Management have been documented within 100 meters (about 330 feet) of this route. Ripley's springparsley and Parish's scorpionweed occur adjacent to Jackass Flats Road on the Nevada Test Site in eastern Rock Valley, and the fringed myotis has been observed near Yucca Mountain in Fortymile Wash. A number of other bats classified as sensitive by the Bureau of Land Management might occur along the route, and the route is within the range of the chuckwalla and gila monster.

The route crosses ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. The route does not cross designated game habitat (DIRS 103079-BLM 1998, Maps 3-7 to 3-9). There are no springs, riparian areas, or other potential wetlands within 0.4 kilometer (0.25 mile) of the intermodal transfer station area or the route.

3.2.2.2.5 *Cultural Resources*

The description of environmental conditions in this section focuses on archaeological and historic resources associated with the candidate intermodal transfer station areas and the associated heavy-haul truck routes. In addition, this section discusses Native American interests in relation to several of the heavy-haul truck routes. Unless otherwise noted, the *Environmental Baseline File for Archaeological Resources* (DIRS 104997-CRWMS M&O 1999, all) and *Additional Baseline Cultural Resources Data for the Nevada Transportation Scenario* (DIRS 155826-Nickens and Hartwell 2001, all) are the bases for the information in this section.

Archaeological and Historic Resources. Archaeological data from the candidate intermodal transfer station sites are very limited. Based on a records search at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, four, seven, and two archaeological sites have been recorded at or near the Caliente, Sloan/Jean, and Apex/Dry Lake sites, respectively. These sites have not been evaluated with regard to their potential eligibility for listing in the *National Register of Historic Places.* The I-15 frontage road that runs through the northern location for the Apex/Dry Lake intermodal transfer station is an unrecorded segment of the former Arrowhead Trail Highway, the first automobile highway through southeastern Nevada. Also in this location are the remains of an unrecorded motel and gas station that were associated with the early highway.

Based on recent work by the cultural resources staff at the Harry Reid Center of the University of Las Vegas, Nevada, railroad construction camps could occur in the Apex/Dry Lake or Sloan/Jean intermodal transfer station locations. Seven of these early 20th-century camps were recently excavated in the vicinity of Apex, along with another construction camp associated with a realignment of the Arrowhead Highway in the 1920s. The “Last Spike” site, where the two stretches of the San Pedro, Los Angeles and Salt Lake Railroad were joined in 1905, is within the existing railroad right-of-way adjacent to the middle of the three properties being considered for the Sloan/Jean intermodal transfer station location. Archaeological remains of associated construction camps could occur there as well.

There is some relevant information about the area of the candidate Caliente intermodal transfer locations, which have been extensively disturbed through their current use. Various cultural groups have occupied the Caliente/Meadow Valley Wash area for at least the past 11,000 years (DIRS 103260-Fowler et al. 1973, all; DIRS 102217-D’Azevedo 1986, all). Previously recorded prehistoric archaeological resources in the region include scattered lithic artifacts, rock shelters, temporary camps, and rock art (DIRS 102201-Kautz and Oothoudt 1992, all). Historic archaeological resources in the region typically consist of remains of late nineteenth- and early twentieth-century activities such as mining and ranching.

The Nevada Department of Transportation has completed archaeological field surveys for each of the rights-of-way for the candidate heavy-haul truck routes (Table 3-58). Only the proposed segment of the Caliente/Chalk Mountain route that extends from Highway 375 across Nellis Air Force Range and the Nevada Test Site has not been surveyed. An archival search of a 0.2-kilometer (0.1-mile)-wide corridor along this route identified five archaeological sites, two of which are not eligible for inclusion on the *National Register of Historic Places*; the other three have not been evaluated.

A number of historic properties occur along the proposed heavy-haul truck routes that have been listed on either the *Nevada State Register of Historic Places* or the *National Register of Historic Places.* These historic properties are shown in Table 3-59.

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Table 3-58. Number of archaeological sites along 0.2-kilometer (0.1-mile)-wide corridors containing the candidate heavy-haul truck routes.

Site	Eligible	Likely not eligible	Unevaluated	Total
Caliente Route				
Historic	4	13	4	21
Prehistoric	5	57	75	137
Historic/prehistoric	1	2	2	5
Unknown	0	3	12	15
Total	***10***	***75***	***93***	***178***
Caliente/Chalk Mountain Route				
Historic	3	3	2	8
Prehistoric	2	10	6	18
Historic/prehistoric	0	1	0	1
Unknown	0	3	1	4
Total	***5***	***17***	***9***	***31***
Caliente/Las Vegas Route				
Historic	3	6	21	30
Prehistoric	4	25	51	80
Historic/prehistoric	0	1	4	5
Unknown	0	3	10	13
Total	***7***	***35***	***86***	***128***
Sloan/Jean Route				
Historic	5	4	19	28
Prehistoric	1	3	23	27
Historic/prehistoric	0	0	1	1
Unknown	0	0	3	3
Total	***6***	***7***	***46***	***59***
Apex/Dry LakeRoute				
Historic	2	3	15	20
Prehistoric	2	16	11	29
Historic/prehistoric	0	0	1	1
Unknown	0	0	1	1
Total	***4***	***19***	***28***	***51***

Table 3-59. Listed cultural resource properties close to proposed heavy-haul truck routes.[a]

Property	Heavy-haul route	Status[b]
Tonopah Multiple Resource Area	Caliente	NRHP
Goldfield Hotel	Caliente	NSRHP
Goldfield Historic District	Caliente	NRHP
Union Pacific Depot, Caliente	Caliente	NRHP
Smith (Scott) Hotel, Caliente	Caliente	NSRHP
Sedan Crater, Area 10, Nevada Test Site	Caliente/Chalk Mountain	NRHP
Black Canyon Petroglyphs	Caliente/Las Vegas	NRHP

a. Source: DIRS 155826-Nickens and Hartwell (2001, Table 6, pp. 17 to 19).
b. NRHP = *National Register of Historic Places*; NSRHP = Nevada State Register of Historic Places.

Native American Interests. Section 3.2.2.1.5 discusses general Native American concerns about transportation routes. The discussion that follows identifies Native American tribes and lands that could be affected by heavy-haul truck routes. Also discussed are resources (crossed by or near heavy-haul truck routes) identified as having significance for Native Americans.

The Moapa Paiute Indian Tribe is a Federally recognized tribe of about 290 Southern Paiute people. The tribe's reservation near the town of Moapa on I-15 and the Union Pacific Railroad's mainline contains homes and business enterprises. The reservation is about 6 kilometers (4 miles) east of the Caliente/Las Vegas heavy-haul truck route and about 5 kilometers (3 miles) north of the Apex/Dry Lake station site (DIRS 102043-AIWS 1998, Chapter 4).

The Las Vegas Paiute Tribe is a Federally recognized tribe of about 100 people living on two separate tribal parcels in southern Nevada (DIRS 102043-AIWS 1998, Chapter 4). One parcel near downtown Las Vegas consists of 73,000 square meters (18 acres) of land with about 20 homes, tribal administrative offices, and various tribal business enterprises. This parcel is about 11 kilometers (7 miles) from an overlapping portion of the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul truck routes (northern Las Vegas beltway for the Las Vegas and Apex/Dry Lake routes, and western Las Vegas beltway for the Sloan/Jean route). The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16.2 square kilometers (4,000 acres) with over 10 homes and various business enterprises. An overlapping portion of the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake heavy-haul truck routes goes through a 1.6-kilometer (1-mile) corner of this parcel.

A land transfer of Bureau of Land Management land at Scottys Junction, Nevada, to the Timbisha Shoshone, a Federally recognized tribe of about 280 people located at Death Valley, California, includes 2.4 kilometers (1.5 miles) of frontage along the south side of U.S. 95 along the Caliente heavy-haul truck route. The Timbisha Shoshone plan to use this land for single-family residences and small-scale economic development (DIRS 154121-DOI 2000, Volume I, p. 19).

Although intensive studies are not yet complete, earlier projects involving Native American fieldwork indicate both the presence of and potential for important resources to occur along the candidate heavy-haul truck routes. Ethnographic fieldwork for the Intermountain Power Project in the early 1980s and, more recently, for the proposed intermodal transportation of low-level radioactive waste to the Nevada Test Site has identified the following areas as having significance for Native Americans:

- The Pahranagut Valley contains several places of importance: Maynard Lake area; Lower Pahranagut Storied Rocks; Upper Pahranagut-Black Canyon (Caliente/Las Vegas route)
- Crystal Springs, near the junction of Highways 93 and 318 (Caliente and Caliente/Las Vegas routes)
- Arrow Canyon Valley along U.S. 93 (Caliente/Las Vegas route)
- Caliente downtown area (hot springs and caves) (Caliente route)
- Caliente painted and pecked Storied Rocks (Caliente intermodal transfer station site and heavy-haul truck route)
- Oak Springs Summit area, along U.S. 93 (Caliente and Caliente/Las Vegas routes)
- Six Mile Flat-Pahroc Summit area, along U.S. 93 (Caliente and Caliente/Las Vegas routes)
- Twin Springs, Twin Springs Slough, and Echo Lakes area, along Highway 375 (Caliente route)
- Warm Springs, at the junction of Highways 375 and 6 (Caliente route)

In addition to the areas listed above, many sacred and culturally important Native American places and resources exist on Nellis Air Force Range and the Nevada Test Site, through which the proposed Caliente/Chalk Mountain heavy-haul truck route passes.

3.2.2.2.6 *Socioeconomics*

The candidate heavy-haul intermodal transfer station sites and routes would not appreciably affect counties other than those in which the facilities were located. Section 3.1.7 contains socioeconomic background information on the three counties (Clark, Lincoln, and Nye) most involved in the heavy-haul truck routes. The Caliente heavy-haul truck route is the only route involving a county outside the region of influence; it passes through Esmeralda County in addition to Lincoln and Nye Counties. Section 3.2.2.1.6 contains socioeconomic information for Esmeralda County.

3.2.2.2.7 *Noise and Vibration*

Most of the proposed routes pass through unpopulated desert with background noise levels of 22 to 38 dBA. All routes pass through small rural communities (see Chapter 6, Figures 6-22 through 6-26). Noise levels in rural communities usually range from 40 to 55 dBA (Table 3-32). Traffic noise along highways generally ranges from 5 to 15 dBA above natural background levels (DIRS 101821-EPA 1974, p. D.5). Roadside noise levels are highly dependent on the volume of traffic, the road surface, composition of the traffic (trucks, automobiles, motorcycles, etc.), and vehicle speed. Measurements taken 90 meters (300 feet) from the centerline of U.S. 95 just outside the Nevada Test Site ranged from 45 to 55 dBA (DIRS 101531-Brown-Buntin 1997, pp. 8 and 9). Less traveled rural highways would have lower 1-hour noise levels, possibly as low as 33 dBA at 90 meters (300 feet) from the centerline. Communities potentially affected by the candidate intermodal transfer stations and associated heavy-haul truck routes were identified by examining the proposed route of each corridor and estimating if construction or heavy-haul vehicle noise could affect area communities. Occasional noise from passing military aircraft occurs near and in the Nellis Air Force Range.

Caliente Station

DOE is considering two parcels of land in Meadow Valley Wash several miles south of Caliente for the intermodal transfer station. A water treatment facility (consisting of drain fields and a pond) adjacent to the larger parcel could contribute to background noise levels. There is a small ranch about 500 meters (1,600 feet) from the larger parcel. The other parcel of land is more remote and has no buildings. Estimated noise levels range from 22 to 45 dBA depending on traffic volume (based on Table 3-32).

Caliente Route. The Caliente heavy-haul truck route goes from Caliente to the Yucca Mountain site, passing through or near the Towns of Caliente, Crystal Springs, Rachel, Tonopah, Goldfield, Beatty, and Amargosa Valley. Estimated noise levels in these communities range from 40 to 55 dBA (based on Table 3-32). This longest route travels on existing highways through predominantly Bureau of Land Management land.

Caliente/Chalk Mountain Route. The Caliente/Chalk Mountain heavy-haul truck route would use existing paved roads to a point in western Lincoln County where it would turn south through the Nellis Air Force Range and the Nevada Test Site. Caliente, Crystal Springs, and Rachel are the only towns through which the heavy-haul truck route would pass. Estimated noise levels in these communities would range from 40 to 55 dBA (based on Table 3-32).

Caliente/Las Vegas Route. The Caliente/Las Vegas heavy-haul truck route follows U.S. 93 from Caliente to I-15, then into Las Vegas primarily on Bureau of Land Management land. The section of the route on the planned Northern Beltway to U.S. 95 would have the highest noise levels, biased toward the 55-dBA level and higher during high traffic volume. Traffic noise levels along U.S. 95 would range from 45 to 55 dBA (DIRS 101531-Brown-Buntin 1997, pp. 8 and 9). Estimated noise levels in Caliente, Crystal Springs, Ash Springs, Alamo, Indian Springs, and Mercury range from 40 to 55 dBA (based on Table 3-32).

Sloan/Jean Station

DOE is considering three parcels of land in the Sloan/Jean area. Some residences, a quarry, and a concrete plant are next to the northernmost site. The eastern parcel is along I-15 adjacent to several commercial enterprises. The third parcel is in the community of Jean and is close to two large casinos. Estimated noise levels in these areas, which are greater than levels encountered in unpopulated desert areas, range from 40 to 55 dBA (based on Table 3-32).

Sloan/Jean Route. The Sloan/Jean heavy-haul truck route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site, and would pass through a number of small towns and the western and northern portions of the Las Vegas Valley. Existing noise levels in the Las Vegas Valley probably range from 52 to 74 dBA; estimated noise levels in Indian Springs, Cactus Springs, and Mercury range from 40 to 55 dBA (based on Table 3-32).

Apex/Dry Lake Station

The candidate location for the Apex/Dry Lake intermodal transfer station is in an unpopulated part of Dry Lake Valley. Existing noise levels are probably somewhat higher than typical levels for a desert environment because of vehicles that travel along I-15 in this area. Depending on local meteorological conditions, noise from the Apex industrial site and passing trains would add to the existing acoustic environment at this site. The northern boundary of one possible location for an intermodal transfer station in the Apex/Dry Lake area is about 3 kilometers (2 miles) south of the Moapa Indian Reservation. There is one manufactured home adjacent to the Dry Lake site.

Apex/Dry Lake Route. The Apex/Dry Lake heavy-haul truck route would use existing paved roads from the intermodal transfer station to the Yucca Mountain site. It would pass through a number of small communities and the north end of the Las Vegas Valley. Existing noise levels in Indian Springs, Cactus Springs, and Mercury probably range from 40 to 55 dBA (Table 3-32). Estimated noise levels in the Las Vegas Valley range from 52 to 74 dBA (based on Table 3-32).

Vibration. The proposed locations of intermodal transfer stations are along existing rail lines. Railroad traffic generates some ground vibration in the vicinity of the line. Depending on the proximity to roads, automobile and truck traffic can create a low level of ground vibration. For the most part, the background vibration levels associated with vehicle traffic are not perceptible to humans, but humans residing close to railroad tracks can perceive some level of ground vibration from trains. Background ground vibration levels are around 52 VdB (root-mean-square velocity) (DIRS 155547-HMMH 1995, p. 7-5) and higher (about 65 VdB) near existing highways and rail lines.

3.2.2.2.8 *Aesthetics*

This section describes the existing aesthetic qualities associated with each of the intermodal transfer station sites and associated heavy-haul truck routes. Section 3.1.10 provides additional description of Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (DIRS 105002-CRWMS M&O 1999, all).

Caliente Station

The proposed location for the Caliente facility is southeast of Caliente, on the western edge of Meadow Valley Wash. This area is in the Caliente Bureau of Land Management resource area and is classified Class III (Figure 3-32). As discussed in Section 3.2.2.2.1, the Caliente intermodal transfer station site is in an area currently used as a wastewater treatment facility and for hay production. The proposed locations are near Kershaw-Ryan State Park (Class II). The entrance to the park is just south of the intermodal transfer station site around a slight bend of topography. The entrance to the park fronts State Route 317 and a Union Pacific mainline.

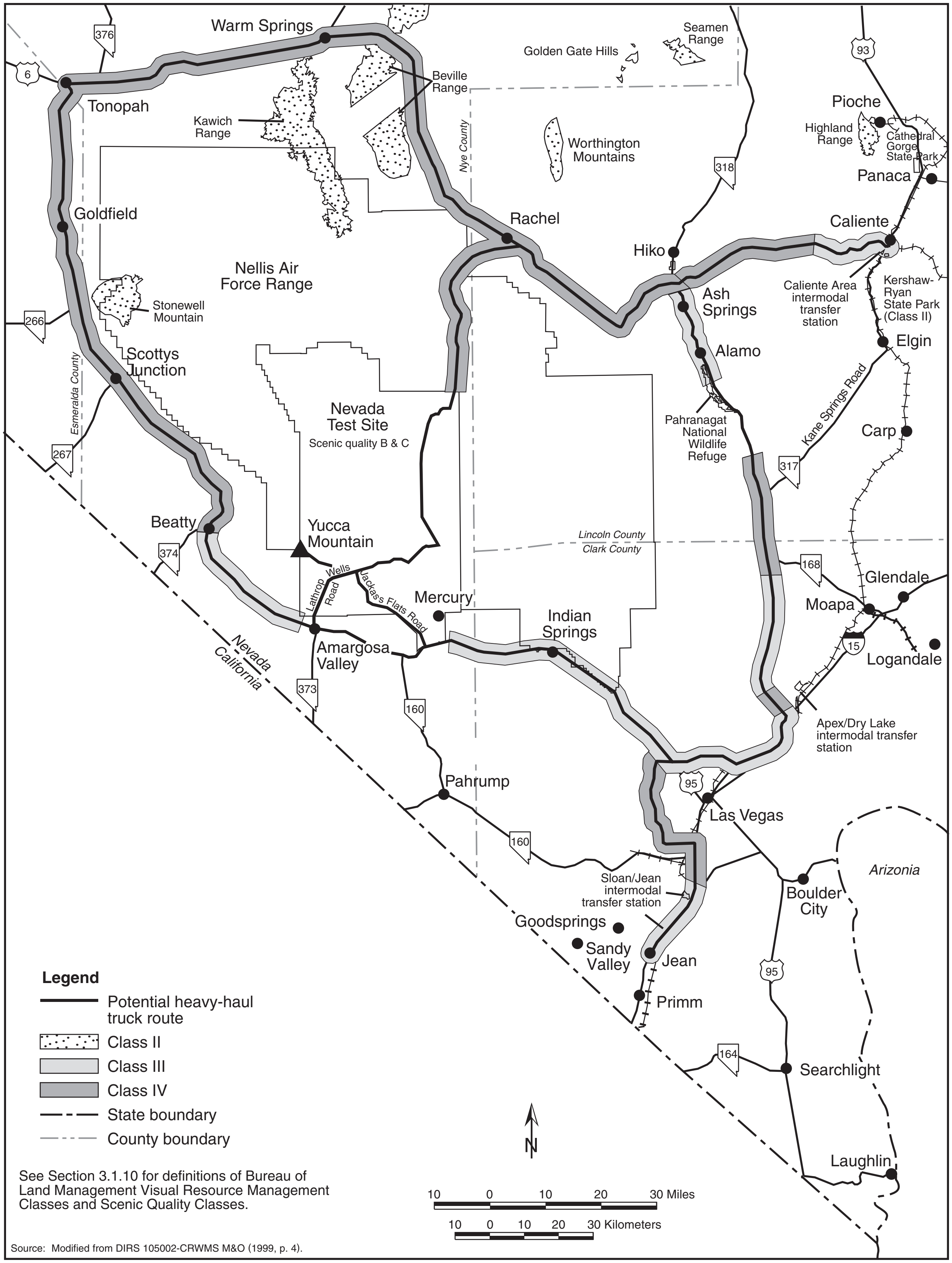


Figure 3-32. Visual Resource Management classes along the potential routes for heavy-haul trucks.

Caliente Route. Section 3.2.2.2.4 describes the environmental setting along the Caliente route. The route passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. From Caliente to the south end of the Burnt Springs Range the route passes through Class III land, and then through Class IV land to Rachel. From Rachel to Tonopah the route crosses Class III land except portions of the Reveille and Kawich Ranges near Warm Springs, which are Class II areas. From Tonopah to Beatty, the route crosses Class IV land, then Class III land from Beatty to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or Class C (Figure 3-32).

Caliente/Chalk Mountain Route. Section 3.2.2.2.4 describes the environmental setting along the route. The route passes through the Caliente and Schell Bureau of Land Management resource areas. From Caliente to the south end of Burnt Springs Range, the route passes through Class III land. From the Burnt Springs Range west through Crystal Springs to Rachel, the route passes through Class IV land. The route from Rachel south crosses Class III and IV land to the Nevada Test Site boundary. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-32).

Caliente/Las Vegas Route. Section 3.2.2.2.4 describes the environmental setting along the Caliente/ Las Vegas route. The route passes through the Caliente, Schell, and Las Vegas Bureau of Land Management resource areas. From Caliente to Crystal Springs the route crosses Class III and Class IV land. From Crystal Springs south to the Pahranagat National Wildlife Refuge, the route crosses Class III land. The refuge is rated Class II. The route from the south end of the refuge to I-15 crosses Class III and IV land.

The remainder of the route along I-15, the Northern Beltway, and U.S. 95 passes through Class III land. Lands crossed on the Nevada Test Site are rated Class B or Class C (Figure 3-32).

Sloan/Jean Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Sloan/Jean intermodal transfer station and associated route. The potential location for the Sloan/Jean intermodal transfer station has three parcels located some distance apart, two near Jean and one near Sloan. All portions of these parcels are in the Las Vegas Bureau of Land Management resource area adjacent to existing roads and rail lines and are designated as Class III lands. From Jean to Sloan the route travels through Class III lands. From Sloan along the Las Vegas Beltway to U.S. 95 is designated as Class IV lands. The portion of the route to the Nevada Test Site is through Class III lands. The remainder of the route on the Nevada Test Site is classified as scenic quality Class B and C (Figure 3-32).

Apex/Dry Lake Station and Route

Section 3.2.2.2.4 describes the environmental setting for the Apex/Dry Lake intermodal transfer station and route. Most of the land in the potential intermodal transfer areas is classified as Class IV lands. At present, the intermodal transfer station parcels are used for recreation, based on observed trails and two-track roads crossing the parcels, and are located near areas already affected by man as discussed in Section 3.2.2.2.1. A small portion of the southern section of land is designated as Class III lands. The entire route passes through Class III lands from the Apex/Dry Lake siding (and the location of the intermodal transfer station) to the Nevada Test Site boundary. On the Nevada Test Site the route to the repository passes through lands with a scenic quality designated as Class B and C (Figure 3-32).

3.2.2.2.9 *Utilities, Energy, and Materials*

The implementation of the heavy-haul approach for transporting spent nuclear fuel and high-level waste to the repository would involve the construction and operation of an intermodal transfer station and upgrades of existing highways. The scope of the utilities, energy, and materials analysis includes consumption of electric power, fossil fuel, and construction materials such as concrete and steel to support these activities. The sites studied for the intermodal transfer station (Caliente, Sloan/Jean, and Apex/Dry Lake) are in areas with at least some light industrial activity or other activity that requires electric power. The sites would, therefore, have access to light industrial levels of electric power. The sites under consideration would also have access to the regional supply capability to provide fossil fuel and construction materials. Heavy-haul truck route upgrades would also use the southern Nevada regional supply system to provide materials for highway upgrades.

3.2.2.2.10 *Environmental Justice*

The candidate location for the Caliente intermodal transfer station is in Lincoln County and the associated heavy-haul truck routes go through Lincoln, Nye, and Esmeralda Counties for the Caliente route; Lincoln and Nye Counties for the Caliente/Chalk Mountain route; and Lincoln, Clark, and Nye Counties for the Caliente/Las Vegas route. Section 3.1.13 discusses minority and low-income populations in Clark, Lincoln, and Nye Counties and includes Figures 3-27 and 3-28, which show locations of minority and low-income communities, respectively, in Nevada. Figures 3-29 and 3-30 provide similar information at a higher resolution for the Las Vegas metropolitan area in Clark County. Section 3.2.2.1.10 discusses minority and low-income populations in Esmeralda County.

The candidate locations for both the Sloan/Jean and Apex/Dry Lake intermodal transfer stations are in Clark County; the associated heavy-haul truck routes both go through Clark and Nye Counties. Section 3.1.13 discusses minority and low-income populations in Clark and Nye Counties.

Some detail on the affected environment for environmental justice that was presented in the Draft EIS for heavy-haul truck routes and intermodal transfer station sites has been deleted because of a change in the nature and level of available information presented. As described in Section 3.1.13, baseline environmental justice data consists of minority populations at the block level based on 2000 Census data (newly available since the Draft EIS) and low-income populations at the block group level based on 1990 Census data. These represent the most up-to-date data in both categories at the time of this document's preparation. Because of the differences in the level of data between the two categories, a combined, parallel discussion is no longer appropriate. The baseline presentation of information now relies on the Section 3.1.13 figures referenced above to identify locations of minority and low-income communities in proximity to the candidate heavy-haul truck routes and intermodal transfer station sites.

3.2.2.2.11 *Existing Traffic on Candidate Routes for Heavy-Haul Trucks*

The description of the affected transportation environment characterizes routes in terms of traffic volume and roadway capability (DIRS 103225-DOE 1998, pp. 3-1 to 3-14). The potential for congestion and other problems on a roadway is expressed in terms of levels of service. The level of service scale ranges from A to F, as follows:

A Indicates free-flow conditions.

B Indicates free-flow, but the presence of other vehicles begins to be noticeable. Average travel speeds are somewhat lower than level of service A.

C Indicates a range in which the influence of traffic density on flow becomes marked. The ability to maneuver in the traffic stream and to select an operating speed is clearly affected by the presence of other vehicles.

D Indicates conditions in which speed and the ability to maneuver are severely restricted due to traffic congestion.

E Indicates full capacity; a disruption, no matter how minor, causes backups to form.

F Indicates breakdown of flow or stop-and-go traffic.

Each level is defined by a range of volume-to-capacity ratios. Level of service A, B, or C is considered good operating conditions in which minor or tolerable delays of service are experienced by motorists. Level of service D represents below average conditions. Level of service E corresponds to the maximum capacity of the roadway. Level of service F indicates a heavily congested or overburdened capacity. Roads outside the Las Vegas metropolitan area are generally level of service A or B; roads inside the Las Vegas metropolitan area are generally level of service E or F. Table 3-60 lists current levels of service on potential heavy-haul truck routes (excluding the planned Las Vegas Beltway).

Table 3-60. Existing levels of service along candidate routes for heavy-haul trucks.[a]

Route segment	Level of service
Caliente	
U.S. 93 to U.S. 6/U.S. 95 interchange	A
U.S. 95/U.S. 6 to Tonopah city limit	C
U.S. 95 (to Mercury, Nevada)	B
Caliente/Chalk Mountain	
Caliente to Rachel	A
Cost of route on U.S. Government Facility	N/A
Caliente/Las Vegas	
U.S. 93 (between I-15 and Caliente)	A
I-15 (to Craig interchange)	A
I-15 (in Las Vegas)	E or F[b]
U.S. 95 (in Las Vegas)	E or F[b]
U.S. 95 (Las Vegas to Mercury)	B
Sloan/Jean	
I-15 (to and in Las Vegas)	C, F[b]
U.S. 95 (in Las Vegas)	C, F[b]
U.S. 95 (Las Vegas to Mercury)	B
Apex/Dry Lake	
I-15 (to Craig interchange	A
I-15 (in Las Vegas)	E and F[b]
U.S. 95 (in Las Vegas)	E and F[b]
U.S. 95 (Las Vegas to Mercury)	B

a. Source: DIRS 103225-DOE (1998, pp. 3-1 to 3-14).
b. Does not consider the Las Vegas Beltway.

3.3 Affected Environment at Commercial and DOE Sites

In response to public comments, DOE has revised Section 3.3 to provide more information on the methodology the Department used to determine baseline conditions at the 72 commercial and 5 DOE sites evaluated under the No-Action analysis. The revisions include added information on the individual site environmental factors (Section 3.3.1) and augmented information on regional environmental factors (Section 3.3.2). In providing this new information, DOE changed the section numbers for the information that appeared in the Draft EIS.

The No-Action Alternative analyzes the impacts of not constructing and operating a monitored geologic repository at Yucca Mountain. It assumes that the spent nuclear fuel and high-level radioactive waste would remain at commercial and DOE sites throughout the United States. This section describes baseline environmental factors at commercial and DOE sites including land use requirements, radiological effluents, worker and offsite populations, and occupational and public radiation doses. These factors provide a basis for comparison of impacts with the Proposed Action and the No-Action Alternative.

In addition to the site environmental factors, this section also includes regional environmental factors for five regions of the United States, including climate, groundwater, waterways, and potentially affected populations. These regional parameters provide the baseline information necessary for estimating potential impacts resulting from the No-Action Alternative Scenario 2 described in Chapter 7 of the EIS.

3.3.1 SITE ENVIRONMENTAL FACTORS

3.3.1.1 COMMERCIAL SITES

At present, there are 103 operating commercial nuclear powerplants at 69 sites in 31 of the contiguous United States. In addition, three sites (Trojan in Oregon, and Humboldt Bay and Rancho Seco in California) have reactors in various stages of decommissioning. The locations of the 72 commercial nuclear powerplants evaluated in this EIS are shown in Figure 3-33. Approximately half of these sites contain two or three nuclear units. There are no commercial nuclear powerplants in Alaska or Hawaii.

3.3.1.1.1 *Land Use and Ownership*

Typically, nuclear powerplant sites and the surrounding areas are flat-to-rolling countryside in wooded or agricultural areas. More than half of the sites have 80-kilometer (50-mile) population densities of fewer than 200 persons per square mile, and more than 80 percent have 80-kilometer densities of fewer than 500 persons per square mile (DIRS 101899-NRC 1996, Section 2.2.1, p. 2-2). The most notable exception is the Indian Point Station, which is within 80 kilometers of New York City, which has a population density of more than 2,000 persons per square mile.

Site areas range from 0.34 square kilometer (84 acres) for the San Onofre Nuclear Generating Station in California to 120 square kilometers (30,000 acres) for the McGuire Nuclear Station in North Carolina. More than half of the plant sites encompass 2 to 8 square kilometers (500 to 2,000 acres). Larger land use areas are usually associated with plant cooling systems that include reservoirs, artificial lakes, and buffer zones. Typically, 0.2 to 0.4 square kilometer (50 to 100 acres) might actually be disturbed during plant construction. Other land commitments can amount to many tens of square kilometers for transmission line rights-of-way and cooling lakes (if used).

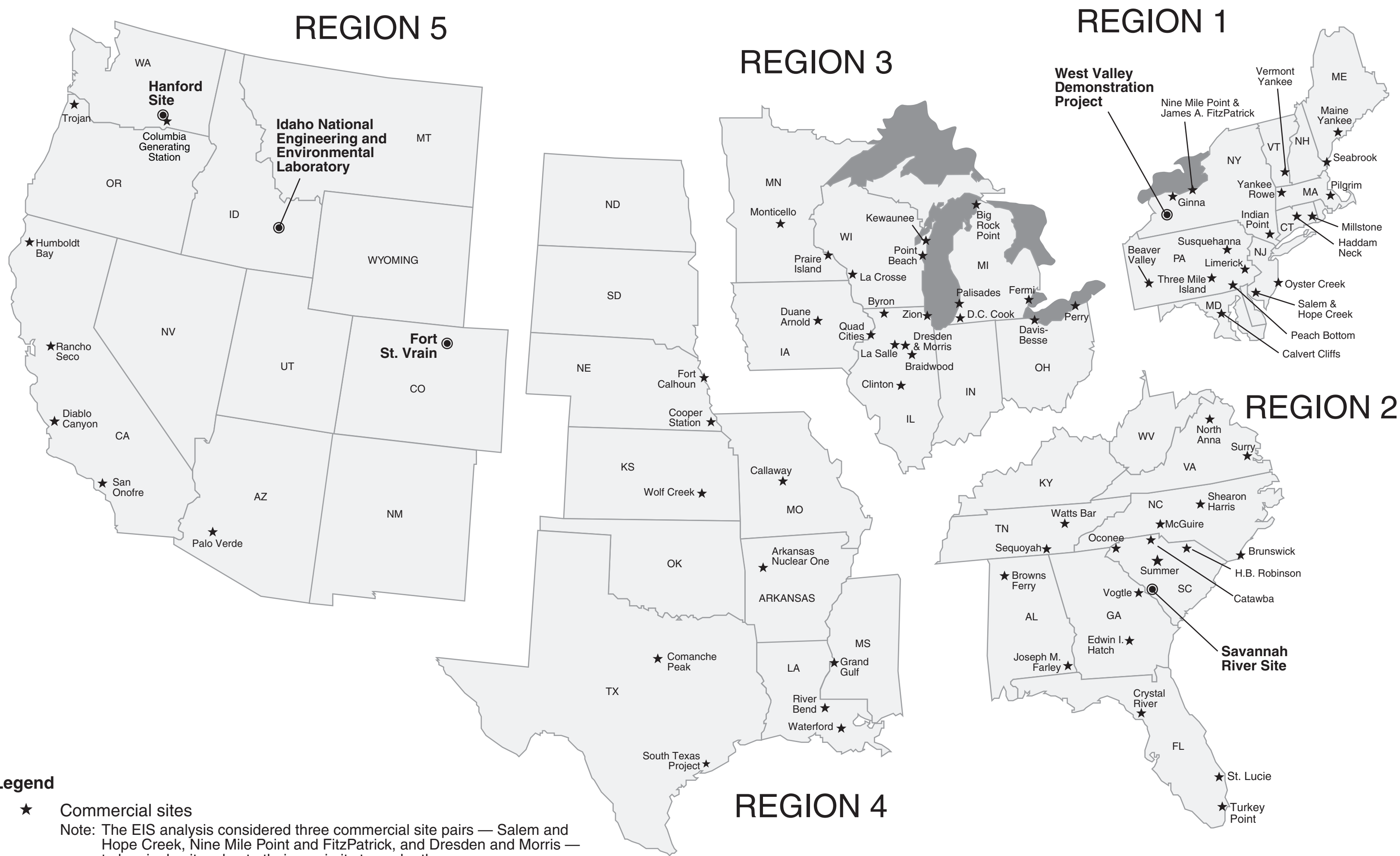
In general, these sites are owned and maintained by the investor owned utilities (sites operated by the Tennessee Valley Authority are Federally owned) that operate the associated power plants and control egress to the sites to protect the health and safety of the public.

3.3.1.1.2 *Socioeconomic Environment*

Although the size of the workforce varies considerably among sites, the average permanent staff size at a nuclear powerplant ranges from 800 to 2,400 people, depending on the number of operating units at the site (DIRS 101899-NRC 1996, Section 2.3.8.1, p. 2-26). In rural or low-population communities, the number of permanent jobs can represent a substantial portion of the local workforce.

In addition to the permanent workforce, many temporary workers are required for tasks that occur during refueling and maintenance outages. Between 200 and 900 additional workers can be employed during these outages to perform the normal maintenance work. Although these temporary workers are in the community for only a short time (usually 1 to 2 months a year), they can have a substantial effect on the area (DIRS 101899-NRC 1996, Section 2.3.8.1, p. 2-27).

In addition to direct employment, plant subcontractors and service industries in the area provide hundreds of indirect jobs. In rural communities, industries that provide this number of jobs at relatively high wages are major contributors to the local economy. In addition to the beneficial effect of these jobs, plant purchasing and worker spending can generate considerable income for local businesses (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).



Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Note: None of the facilities evaluated are located in Alaska or Hawaii.

Source: Modified from DIRS 101911-Poe (1998, p. 2).

Figure 3-33. Commerical and DOE sites in each No-Action Alternative analysis region.

A nuclear powerplant represents an investment of several billion dollars. Such an asset on the tax rolls is extraordinary for rural communities and can constitute the major source of local revenues for small or remote taxing jurisdictions. This revenue often enables higher quality and more extensive public services with lower tax rates to the citizens (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).

For these reasons, nuclear powerplants can have a significant positive effect on the local community environment. These effects are stable and long-term. Because these effects generally enhance the economic structure of the local community, nuclear powerplants become a major positive contributor to the local area (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).

3.3.1.1.3 *Radioactive Effluents*

During normal operations, nuclear powerplants release small amounts of radioactive materials to the environment through atmospheric and aquatic pathways. These radioactive materials, released under controlled conditions, include fission and activation products. Releases to the atmosphere consist primarily of the noble gases and some of the more volatile materials like tritium, isotopes of iodine, and cesium. Releases to aquatic pathways consist primarily of nonvolatile fission and activation products such as isotopes of cesium and cobalt. After appropriate holdup and processing, these materials are monitored carefully before and during releases to determine whether the licensed release limits can be met (for example, 10 CFR Part 20, Appendix I to 10 CFR Part 50, 10 CFR 50.36a, and 40 CFR Part 190).

In 1993 (the last year for which information is readily available), boiling-water and pressurized-water reactors released about 31,000 and 28,000 curies, respectively, of fission and activation gases to the atmosphere (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 1 and 2, pp. 6-12). Thus, the estimated average atmospheric release per boiling-water reactor and pressurized-water reactor was 760 and 380 curies per year, respectively.

In addition, boiling-water reactors and pressurized-water reactors released 0.75 and 0.30 curies, respectively, of iodine-131 and particulates to the atmosphere (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 3 and 4, pp. 12-17). This resulted in boiling-water reactor and pressurized-water reactor average unit releases of 0.018 and 0.0041 curies, respectively.

Liquid releases of tritium in 1993 for boiling-water reactors and pressurized-water reactors totaled about 530 and 36,000 curies, respectively (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 5 and 6, pp. 18-24), and about 11 and 35 curies, respectively (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 7 and 8, pp. 24-29), of mixed fission and activation products.

3.3.1.1.4 *Occupational and Public Health and Safety*

Occupational Radiation Exposures

Nuclear plant workers who conduct activities involving radioactively contaminated systems or who work in radiation areas can be exposed to radiation. Most of the occupational radiation dose to such workers results from external radiation rather than internal exposure to inhaled or ingested radioactive materials. Pursuant to reporting requirements of 10 CFR 20.2206, the Nuclear Regulatory Commission received annual reports from 104 licensees that operated commercial nuclear power reactors in 1999. These reports consisted of radiation exposure records for each monitored individual. The reports are analyzed for trends and summarized in annual reports (DIRS 155099-Karagiannis and Hagemeyer 2000, all) in terms of collective dose and the distribution of dose among the monitored individuals.

In 1999, the total collective occupational dose for all operating commercial reactors was almost 14,000 person-rem or an average per licensee of 131 person-rem (DIRS 155099-Karagiannis and Hagemeyer 2000, Table 3.2, p. 3-5). This total collective dose was received by about 114,000 monitored workers for an average annual individual dose of 120 millirem, which is about 40 percent of the average background radiation dose for the United States, as listed in Table 3-30. However, of the 114,000 monitored workers, about half (55,000 workers) had no measurable dose. Of the approximately 59,000 workers who had a measurable dose, the estimated annual average radiation exposure was 230 millirem, or about 77 percent of the national average background radiation dose of 300 millirem.

In addition to nuclear powerplant licensees, in 1999 the Nuclear Regulatory Commission received annual radiation exposure reports from two Independent Spent Nuclear Storage Facility operators. The reported annual collective dose for these two licensees was 5 person-rem received by 86 monitored individuals, for an annual average of 60 millirem. Of the monitored individuals, only 33 received measurable radiation doses for an annual average of 150 millirem. These doses represent 20 and 50 percent, respectively, of the national average background radiation dose of 300 millirem.

Public Radiation Exposures

Releases of radioactive materials from nuclear power reactors result in radiation doses to humans that are small in relation to doses from natural background radiation. Persons can be exposed to radiation from nuclear power reactors through atmospheric and aquatic pathways. When an individual is exposed through one of these pathways, the dose is determined by the amount of the radioactive material a person could inhale or ingest. The amount of radioactive material inhaled or ingested is determined by the exposure time and the radioactive material concentrations in the various environmental media. The resulting dose is determined by radionuclide-specific dose conversion factors, which are based on physical decay and metabolic properties of the radioactive material in the body.

The major exposure pathways include the following:

- Inhalation of contaminated air
- Drinking milk or eating meat from animals that graze on open pasture on which radioactive contamination might fall
- Eating vegetables grown near the site
- Drinking water or eating fish caught near the point of discharge of liquid effluents

Other less important exposure pathways include external irradiation from surface deposition; consumption of animals that drink irrigation water that might contain liquid effluents; consumption of crops grown near the site using irrigation water that might contain liquid effluents; shoreline, boating, and swimming activities; and direct radiation to offsite individuals.

In 1992 (the last year for which information is readily available), the estimated total population doses for populations living within 80 kilometers (50 miles) of operating nuclear power reactors were 32 person-rem by waterborne pathways and 15 person-rem by airborne pathways, for a total of 47 person-rem (DIRS 155092-Aaberg and Baker 1996, Table 1.4, p. 1.9). However, estimated population dose commitments for the waterborne and airborne pathways varied widely among the sites. The total dose commitments from both pathways for individual sites varied from a high of 3.7 person-rem to a low of 0.0015 person-rem. The arithmetic mean for the total dose from liquid pathways (0.44 person-rem) and airborne pathways (0.21 person-rem) was 0.66 person-rem (DIRS 155092-Aaberg and Baker 1996, p. 1.11). The estimated average annual dose to the offsite individual living within 80 kilometers was 0.0003 millirem, which is a very small fraction of the average annual dose from natural background radiation of 300 millirem in the United States.

In addition to average population doses, maximally exposed individual doses were estimated for commercial nuclear power sites for comparison with the 10 CFR Part 50, Appendix I, numerical guides for design objectives [10 CFR 50.34a(a)], which require nuclear powerplant licensees to design and operate their facilities in a manner that maintains offsite doses from liquid and atmospheric effluents *as low as reasonably achievable*. For the more than 70 sites reporting in 1992, the arithmetic mean of the maximum annual dose from atmospheric pathways for an offsite individual living at the nearest residence was about 0.012 millirem from releases of noble gases and 0.27 millirem to any organ (thyroid, lung, etc.) from releases of iodines and particulate material. For the liquid pathways, the arithmetic mean of the *maximally exposed individuals* for all reporting sites was about 0.12 millirem (DIRS 155092-Aaberg and Baker 1996, Table 1.4, p. 1.9).

For the waterborne pathways, tritium, zinc-65, and isotopes of cesium accounted for 31, 14, and 43 percent of the total dose, respectively. For the airborne pathways, tritium and isotopes of xenon accounted for 44 and 46 percent of the dose, respectively (DIRS 155092-Aaberg and Baker 1996, Table 1.8, pp. 1.17 through 1.22).

3.3.1.2 DOE SITES

This EIS focuses on the five DOE sites at which spent nuclear fuel and high-level radioactive waste currently exists or where existing Records of Decision have authorized placement of these materials (see Chapter 7, Section 7.2 for details). The five sites are the Hanford Site, the Idaho National Engineering and Environmental Laboratory, Fort St. Vrain (spent nuclear fuel only), the West Valley Demonstration Project (high-level radioactive waste only), and the Savannah River Site (Figure 3-33).

3.3.1.2.1 *Land Use and Ownership*

Of the five DOE sites that manage spent nuclear fuel and high-level radioactive waste, three (Hanford Site, Idaho National Engineering and Environmental Laboratory, Savannah River Site) are on large tracts of Federally owned land ranging from 2,300 square kilometers (890 square miles) for Idaho National Engineering and Environmental Laboratory to 800 square kilometers (310 square miles) for the Savannah River Site. On these three sites, most of the land is undeveloped or forest management areas. These undeveloped areas serve as buffer zones between the operating areas and the public. Access to these sites is controlled for national security purposes to prevent ingress by unauthorized personnel.

The Fort St. Vrain Independent Spent Nuclear Fuel Installation and West Valley Demonstration Project are on much smaller tracts of land, 3.8 acres and 220 acres, respectively, which are mostly developed but are surrounded by low-population-density lands used mostly for agricultural and residential purposes.

3.3.1.2.2 *Socioeconomic Environment*

Because of their large employment base, the Hanford Site, Idaho National Engineering and Environmental Laboratory, West Valley Demonstration Project, and Savannah River Site represent a substantial portion of their respective local workforces. For example, in December 1997 the Hanford Site employed almost 11,000 DOE and contractor personnel, which represented 13 percent of the total employment in the area (DIRS 156931-DOE 2000, p. 4-101). Similarly, in 1998 Idaho National Engineering and Environmental Laboratory and Savannah River Site employed 8,100 and 14,000 workers, respectively, which represented about 7 percent of their local area workforces (DIRS 156914-DOE 2000, all). In 1993, the West Valley Demonstration Project employed more than 1,000 DOE and contract workers and was the largest local employer; these workers represented almost 4 percent of the local workforce (DIRS 101729-DOE 1996, p. 4-58).

In 1995, approximately 230 persons worked at the Fort St. Vrain site. Of these, approximately 16 full-time-equivalent personnel worked on the Independent Spent Fuel Storage Facility (DIRS 103213-DOE 1996, Appendix E, Section 3, pp. 3-53 and 54). Based on the 1980 census, the population within an 8 kilometer (5-mile) radius of the site was 3,148, with 1,662 residing in the Town of Platteville. The projected population for 2012 (through the 20-year license) for this area will be 4,526, with 3,040 residing in Platteville. However, even with this relatively small local workforce, the 16 workers and the DOE site would have minimal impact.

In addition to base employment, DOE sites contribute to the local economic conditions through the creation of indirect employment and through the purchase of goods and services from local firms.

3.3.1.2.3 *Radioactive Effluents*

As a result of ongoing process and *remediation* activities, most DOE sites routinely release quantities of radioactive materials to the atmosphere and surface waters that eventually enter the surrounding environment. These effluents are carefully monitored at their points of discharge to ensure that releases remain within limits specified by DOE Orders and applicable state and Federal statutes and regulations.

Radioactive materials released from DOE sites consist of fission and activation products (such as tritium, cesium, strontium, iodine, and krypton), transuranics (such as plutonium and americium), and source material (such as uranium). Atmospheric releases consist primarily of tritium and noble gases (such as krypton and argon), and liquid releases consist primarily of tritium with much smaller quantities of fission products and transuranics. The Idaho National Engineering and Environmental Laboratory typically does not release radioactive liquid effluents off the site. Rather, liquid effluents are sent to two plastic-lined evaporation ponds (DIRS 156914-DOE 2000, Section 7.1, p. 7-3) that prevent percolation of contaminated water into the ground and eventual release to the *accessible environment*. In addition, the Hanford Site 200-Area facilities discharge radioactive liquid effluents to the 616-A-Crib (also known as the State-Approved Land Disposal Site) rather than directly to the Columbia River (DIRS 156931-DOE 2000, Section 3.1.3, p. 3.6). The Fort St. Vrain site does not have atmospheric or liquid effluents (DIRS 155101-DOE 1998, Section 2.3.4.1, p. 2-25 and Section 2.4.2, p. 2-35) because the spent nuclear fuel is stored in sealed canisters and is not typically handled or processed.

In 1999, the four DOE sites with radioactive effluents discussed in this section released about 92,000 *curies* of fission and activation products to the atmosphere (DIRS 156914-DOE 2000, Table 7-1, p. 7-4; DIRS 156931-DOE 2000, Table 3.1.1, p. 3.6; DIRS 155094-Arnett and Mamatey 2000, Table 4, p. 13; DIRS 154284-WVNS 2000, Tables D-2 through D-11, pp. D-4 through D-12). Most of these releases occurred at the Savannah River Site, which released about 89,000 curies. The Savannah River Site atmospheric releases consisted almost entirely of tritium (about 52,000 curies) and noble gases (about 37,000 curies). In addition, the four sites released 0.0025 curie of transuranics and 0.048 curie of source material to the atmosphere.

In 1999, the DOE sites released about 6,400 curies of fission and activation products in liquid effluents (DIRS 156914-DOE 2000, Table 7-2, p. 7-5; DIRS 156931-DOE 2000, Tables 3.1.3 and 3.1.4, p. 3.7; DIRS 155094-Arnett and Mamatey 2000, Table 6, p. 22; and DIRS 154284-WVNS 2000, Table C-1, p. c-3). More than 99 percent of these releases consisted of tritium, and most (about 6,300 curies) occurred at the Savannah River Site.

3.3.1.2.4 *Occupational and Public Health and Safety*

Occupational Radiation Exposures

In 1999, DOE reported a total workforce (including contractors) of approximately 130,000 individuals (DIRS 155091-DOE 1999, Exhibit 3-1, p. 3-2). Of these individuals, about 113,000 were monitored for potential radiation exposure. Only about 17,000 received measurable doses. The collective dose is the sum of the doses received by all individuals who had measurable doses, and is reported in person-rem. The collective dose is an indicator of the overall radiation exposure at DOE facilities and includes doses to all DOE employees, contractors, and visitors. DOE monitors the collective dose as one measure of the overall performance of radiation protection programs to keep individual and collective exposures as low as reasonably achievable.

For the five sites discussed in this section, DOE reported a total collective dose of about 380 person-rem for 1999 (DIRS 155091-DOE 1999, Exhibit 3-17, p. 3-17). This dose was received by almost 6,000 individuals with measurable doses, for an average annual dose of about 60 millirem per person. This dose represents 20 percent of the national average background dose of 300 millirem. The Fort St. Vrain site reported no measurable doses for 1999.

Public Radiation Exposures

In a manner similar to that described in Section 3.3.1.1.4 for commercial sites, DOE estimates collective and individual doses for populations living within 80 kilometers (50 miles) of their operations facilities. In 1999, for the five DOE sites discussed in this section, the total estimated offsite population dose was about 7.1 person-rem. This dose was received by a total 80-kilometer population of about 2.5 million people for an average dose of about 0.003 millirem per person, which is a very small fraction of the average annual dose from natural background radiation of 300 millirem in the United States (DIRS 156914-DOE 2000, Table 8-3, p. 8-9; DIRS 156931-DOE 2000, Table 5.0.2, p. 5.9; DIRS 155090-Arnett and Mamatey 2000, Table 7-2, p. 118, p. 121; DIRS 155094-Arnett and Mamatey 2000, Table 32, p. 125; DIRS 154284-WVNS 2000, Table 4-2, p. 4-7). Most of this collective dose (6.6 person-rem) was received by persons living around and downstream of the Savannah River Site and is attributed to atmospheric and liquid releases of tritium (3.5 person-rem) (DIRS 155094-Arnett and Mamatey 2000, Table 41, p. 135 and Table 48, p. 144). Fort St. Vrain reported that radioactive effluents and direct radiation from the site in 1999 did not contribute to any increase in offsite doses (DIRS 155093-Newkirk and Hall 2000, p. 7).

In addition to average population doses, DOE estimated doses for the hypothetical maximally exposed offsite individual. For the four sites with reported offsite doses, the maximally exposed offsite individual received a maximum dose of 0.28 millirem (DIRS 155100-DOE 1999, p. 8-4; DIRS 155097-DOE 1999, p. 5.4; DIRS 155090-Arnett and Mamatey 2000, p. 122; DIRS 154284-WVNS 2000, Table 4-2, p. 4-7), primarily from atmospheric and liquid releases of tritium (0.10 millirem) and liquid releases of cesium-137 (0.13 millirem) (DIRS 155094-Arnett and Mamatey 2000, Table 42, p. 136, and Table 45, p. 141).

3.3.2 REGIONAL ENVIRONMENTAL FACTORS

For analytic purposes, DOE divided the country into five regions (see Figure 3-33). This section describes the affected environment for each region that reflects the average or mean conditions of the sites in the region. The affected environment includes spent nuclear fuel and high-level radioactive waste inventories, climatic parameters, groundwater flowrates, downstream surface-water users, and downstream surface-water flowrates. In all cases, DOE used data consisting of average or mean conditions from actual sites to develop hypothetical sites.

To develop the hypothetical sites, DOE divided the generator sites among the five regions (Figure 3-33). Climate varies considerably across the United States. Radionuclide release rates would depend primarily on the interaction of climate and materials. DOE analyzed release rates for a hypothetical site in each region that was a mathematical representation of the actual sites in that region. The development process for the hypothetical site used weighted values for material inventories, climate, and groundwater flow information from each actual site to ensure that the results of the analyses of the hypothetical site were comparable to the results for each actual site, if analyzed independently. Similarly, the process constructed downstream populations of water users and river flow for the hypothetical sites from population and river flow data for actual sites, so they reflect the populations downstream of actual storage facilities and the actual amount of water those populations use.

3.3.2.1 REGIONAL INVENTORIES OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

Table 3-61 lists the Proposed Action quantities of commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste in each of the five regions. The information in the table is a projection of quantities and forms that would exist at a point in the future, not as they currently exist. For example, high-level radioactive waste is listed in the table as having gone through a vitrification process with subsequent packaging in canisters, as if ready for disposal in a repository.

Table 3-61. Proposed Action quantities of spent nuclear fuel (metric tons of heavy metal) and canisters of high-level radioactive waste in each geographic region.[a,b]

Region	Commercial spent nuclear fuel[c,d]	DOE spent nuclear fuel[e]	High-level radioactive waste[f,g]
1	16,800	0	300
2	18,900	30	6,000
3	14,700	0	0
4	7,200	0	0
5	5,400	2,300	2,000
Totals	63,000	2,300	8,300

a. Source: Appendix A.
b. Totals might differ from sums due to rounding.
c. Analyzed as stored on surface, as shown on Chapter 2, Figures 2-32, 2-33, and 2-34.
d. Includes plutonium in mixed-oxide spent nuclear fuel, which is assumed to behave like other commercial spent nuclear fuel.
e. A representative or surrogate fuel that consisted primarily of N-reactor fuel.
f. Includes plutonium in can-in-canister.
g. Historically, a canister of high-level radioactive waste has been assumed to be equivalent to about 0.5 MTHM (see Appendix A, Section A.2.3.1).

3.3.2.2 CLIMATIC FACTORS AND MATERIAL

DOE assumed that a single hypothetical site in each region would store all the spent nuclear fuel and high-level radioactive waste in each region. Such a site does not exist, but DOE used it for this analysis. To ensure that the calculated results of the regional analyses reflected the appropriate inventory, facility and material degradation, and radionuclide transport, DOE developed the spent nuclear fuel and high-level radioactive waste inventories, engineered barriers, and environmental parameters for the hypothetical site from data from the actual sites in that region. Weighting criteria accounted for the different amounts and types of spent nuclear fuel and high-level radioactive waste at each site, so the results of the analyses of the hypothetical site were representative of the sum of the results if DOE had modeled each actual site independently. If there are no storage areas in a particular part of a region, DOE did not analyze the environmental parameters of that part (for example, there are no storage facilities in the Upper Peninsula of Michigan, so the analysis for Region 3 did not include environmental parameters from cities in the Upper Peninsula). In addition, if the storage area would not affect drinking water (for example, groundwater near the Calvert Cliffs Nuclear Generating Plant outcrops to the Chesapeake Bay), the regional hypothetical storage facility did not include their fuel inventories.

The following climate parameters are important to material degradation times and rates of release:

- Precipitation rate (amount of precipitation per year)
- Rain days (percent of days with measurable precipitation)

- Wet days (percent of year that included rain days and days when the relative humidity was greater than 85 percent)

- Temperature

- Precipitation chemistry (pH, chloride anions, and sulfate anions)

Table 3-62 lists the regional values for each parameter. Appendix K contains more information on the selection and analysis of these parameters.

Table 3-62. Regional environmental parameters.

Region	Precipitation rate (centimeters per year)[a]	Percent rain days (per year)	Percent wet days (per year)	pH	Precipitation chemistry: Chloride anions (weight percent)	Precipitation chemistry: Sulfate anions (weight percent)	Average temperature (°C)[b]
1	110	30	31	4.4	6.9×10^{-5}	1.5×10^{-4}	11
2	130	29	54	4.7	3.9×10^{-5}	9.0×10^{-5}	17
3	80	33	42	4.7	1.6×10^{-5}	2.4×10^{-4}	10
4	110	31	49	4.6	3.5×10^{-5}	1.1×10^{-4}	17
5	30	24	24	5.3	2.1×10^{-5}	2.5×10^{-5}	13

a. To convert centimeters to inches, multiply by 0.3937.
b. To convert degrees Centigrade to degrees Fahrenheit, add 17.78 and then multiply by 1.8.

3.3.2.3 GROUNDWATER PARAMETERS

Most of the radioactivity and metals from degraded material would seep into the groundwater and flow with it to surface outcrops to rivers or streams. Therefore, the analysis had to account for the groundwater characteristics at each site, including the time it takes the water to move through the unsaturated zone and the aquifer. The analysis assumed that the storage facilities would be 490 meters (1,600 feet) up the groundwater gradient from the hypothetical reactor and used this assumption to calculate the time it would take contaminants to reach surface water. Table 3-63 lists the ranges of groundwater flow times in each region. Appendix K contains more information on the sources of groundwater data.

Table 3-63. Ranges of flow time (years) for groundwater and contaminants in the unsaturated and saturated zones in each region.

Region	Contaminant K_d[a] (milliliters per gram)	Unsaturated zone: Water flow time	Unsaturated zone: Contaminant flow time	Saturated zone: Groundwater flow time	Saturated zone: Contaminant flow time	Total contaminant flow time
1	0[b] - 100	0.7 - 4.4	0.4 - 2,100	0.3 - 56	10 - 5,000	10 - 6,000
2	10 - 250	0.6 - 10	35 - 5,000	3.3 - 250	11 - 310,000	460 - 310,000
3	10 - 250	0.5 - 14	32 - 1,500	1.3 - 410	9 - 44,000	65 - 45,000
4	10 - 100	0.2 - 7.1	110 - 2,300	3.9 - 960	300 - 520,000	460 - 520,000
5	0 - 10	0.9 - 73	14 - 4,700	1.7 - 170	0 - 25,000	200 - 26,000

a. K_d = equilibrium adsorption coefficient.
b. The K_d would be 0 if there was no soil at the site.

3.3.2.4 AFFECTED WATERWAYS

Most of the estimated population dose for the No-Action Alternative would be a result of drinking contaminated surface water. The first step in determining the population dose was to identify the waterways that receive groundwater from beneath existing storage facilities (Figure 3-34) and the number of public drinking water systems that draw water from the potentially contaminated waterways

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Figure 3-34. Major waterways near commercial and DOE sites.

(Table 3-64). DOE calculated the river flow past each population center (Section 3.3.2.5) along each river, and used this number in the calculation to determine dose to the population.

Table 3-64. Public drinking water systems and the populations that use them in the five regions.[a]

Region	Drinking water systems	Population
1	85	10,000,000
2	150	5,600,000
3	150	12,000,000
4	95	600,000
5	6	2,800,000
Totals	***486***	***31,000,000***

a. Sources: Based on current information and the 1990 census.

3.3.2.5 AFFECTED POPULATIONS

After identifying the affected waterways, DOE identified the populations that get their drinking water from those waterways. The total population using the river was expressed as number of people per cubic foot per second. If a river system traverses more than one region (for example, the Mississippi drains three regions), weighting criteria accounted for materials received from storage facilities upstream of the region that would flow past several downstream population centers, as necessary. Table 3-64 lists the number of people using the public drinking water systems potentially affected by the degradation of radioactive materials.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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